

**REPORT AND RECOMMENDATIONS  
of  
PROVINCIAL OFFICER  
for  
INCO LIMITED OPERATIONS  
in the  
REGIONAL MUNICIPALITY OF SUDBURY**



**Ontario**

**Ministry  
of the  
Environment**

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REPORT AND RECOMMENDATIONS

of

PROVINCIAL OFFICER

MADE UNDER SECTION 83

of the

ENVIRONMENTAL PROTECTION ACT, 1971

for the

INCO LIMITED

COPPER CLIFF SMELTER

IRON ORE RECOVERY PLANT COMPLEX

NICKEL REFINERY

in the

REGIONAL MUNICIPALITY OF SUDBURY

June 21, 1978.

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### SOURCES SURVEYED

A survey of the Copper Cliff Smelter, the Iron Ore Recovery Plant and the Nickel Refinery owned and operated by Inco Limited was conducted during 1977/78.

### REASON FOR SURVEY

At the time of the survey, there was reason to believe that the three plants in question, were sources of contaminants to the natural environment. This survey was conducted to identify and evaluate the sources within the plants and to recommend measures as required to abate pollution from these sources.

### PLANT LOCATIONS

The plants surveyed are located in the Regional Municipality of Sudbury, and more specifically, the Iron Ore Recovery Plant (I.O.R.P.) complex, including the C.I.L. acid plants (3) and the Nickel Refinery are located in Walden, and the Smelter complex is situated in the community of Sudbury.

The location of the plants are noted on the accompanying map, Figure 1.

## PROCESS DESCRIPTION

Ores from thirteen (13) mines are concentrates in three (3) mills, namely the Frood-Stobie Mill, Clarabelle Mill and Shebandowan Mill. Bulk concentrates from these mills are further processed in the Copper Cliff Mill.

The Smelter receives concentrates from the Copper Cliff Mill and the Shebandowan operation, as well as Thompson residue and internal recycled flue dust as feedstocks. The smelter utilizes quartz from the Lawson quarry and Garson sand as flux agents.

The Iron Ore Recovery Plant receives pyrrhotite feedstock, from the Copper Cliff Mill, via a pipeline.

The Nickel Refinery uses nickel sulphide crudes and precious metal bearing intermediates from the Smelter as feedstocks.

### i) COPPER CLIFF SMELTER

The Smelter can be considered to be a processing unit designed to eliminate iron, sulphur and other impurities from the feedstocks and to consist of three distinct and separate processing areas, namely the copper concentrate circuit, the nickel concentrate circuit and the matte processing circuit. Atmospheric emission sources are listed in Table I and located in the plant complex in Figure 2. Figure 3 is a process block diagram.

## The Nickel Concentrate Circuit

The nickel circuit receives a nickel concentrate feed containing approximately 10% Ni, 3% Cu, 33% Fe, 29% S, silica, gangue (worthless minerals) and trace precious metals. Initially the concentrate, through a series of bin/conveyor/weighing systems, is mixed with a flux, (Garson sand) which is automatically proportioned in accordance with the silica concentration (25% to 30% by weight). This mixture is conveyed to the top of Herreshoff Roasters. There are 32 Herreshoff Roasters which may be operated, and one Fluid Bed Roaster located on number 1 reverberatory furnace (not operating at present), which performs essentially the same function as approximately 8 Herreshoff Roasters. Each Herreshoff Roaster has a throughput capability of approximately 300 wet tons per day of concentrate and flux. Each Herreshoff Roaster has 11 hearths and is approximately 40 feet high with an inside diameter of 20 feet. Rabble arms (rotate at about 1.5 RPM) work the material down through the roaster, hearth by hearth.

The charge is heated as it passes through the hearths in the roaster by natural gas and by the exothermic oxidation of iron sulphide to produce iron oxide and sulphur dioxide. The calcine or roasted concentrate (12.5% sulphur) is discharged from the bottom of the roasters.

The off gases from the roasters are vented through the #1 electrostatic precipitator to the 1250' chimney (see

Figure 2). The flue dust (precipitator catch) is charged to the reverberatory furnaces. Fugitive gas losses from the Herreshoff Roasters are vented to atmosphere via four roof fans.

Calcine, at 1400°F, flows by gravity into surge bins and then to conveyors, that run the length of each side of the reverberatory furnace, entering the furnace through fettling pipes. There are a total of 6 reverberatory furnaces (number 1 has been shut down), and, the number in operation varies between 2 and 5.

Each reverberatory furnace is approximately 30 feet wide and 110 feet long. The furnace is fired by oil but can be converted to natural gas or coal. Air enriched with oxygen is also charged in the reverberatory furnace. Each furnace can smelt approximately 1500 tons of solid charge daily and treats 700 tons of recycled slag from the converters.

The feed is smelted in the reverberatory furnace, with combustion temperatures reaching up to 3000°F. Molten iron oxide combines with silica (if enough is available) to form a liquid iron silicate slag. The iron silicate slag is essentially immiscible with and lighter than the sulphides (mostly iron, copper and nickel) and the bath separates into two layers (slag and matte). Slag is skimmed off the top layer into 35 ton pots on cars and hauled to the slag dump. The iron-nickel-copper matte is tapped from the reverberatory furnace into ladles and charged to converters.

Gases from the slag skimmer and matte tapping operations, including the matte tunnel, are vented via forced draft fans to the 150' level and exhausted to the natural environment. There are 5 monitors (vents 19' x 24') above the reverberatory furnaces for exhausting fugitive emissions. The process gases from the reverberatory furnaces pass through boilers, electrostatic precipitator #4 and then are vented to the 1250' chimney (see Figure 2). The flue dust from electrostatic precipitator #4 is charged back to the reverberatory furnaces.

There are 19 converters (Pierce-Smith) in the smelter, normally 14 in the nickel circuit, however, the arrangement is flexible. The converters are operated on a batch cycle lasting approximately 24 hours.

The Pierce-Smith converters charged in a series of steps, with matte, flux and oxygen enriched air, oxidize the remaining iron sulphide to produce  $\text{SO}_2$  and eliminate iron from the matte as an iron-silicate slag. Generally, within each step, blowing with oxygen enriched air continues until enough iron sulphide is oxidized and fluxed with silica to yield a substantial amount of slag. The slag is then skimmed off and returned to the reverberatory furnaces and matte from the reverberatory furnaces is added to bring the charge back to the working level. Cold charge (scrap, reverts and quartz) may be added so that excessive heat buildup from the oxidation of sulphur does not harm the refractory brick. This stepwise process continues until most of the iron is removed. Finished matte from the converter is approximately 45% nickel, 20% copper, 0.5% iron and 22% sulphur.

The converter matte is cast in 25 ton ingots in molds at 1800°F and cooled in the casting building. The fire clay molds (12' x 8' x 2' with 45° sides) help promote slow cooling. The ingot cools to about 900°F, 3 days after pouring, when it is uncovered and left for a day to cool to approximately 400°F. The slow cooling of matte promotes the growth of large crystals of copper sulphide and nickel sulphide.

Three of the nickel converters, number 1, 3 and 5 converters, have been lengthened from the conventional Pierce-Smith converters and equipped with water cooled hoods. These hoods are tight fitting and allow minimal dilution air to enter the process off gases when the converter opening is directly under the hood. In addition, these converters have a double flue system with a damper control such that process gases can be ducted to either a "weak" or "strong" gas flue. The heated water from the hoods recycles to a cooling tower which exhausts via the 350' Orford chimney. The strong gas flue from these converters (when the converter opening is under the hood) is ducted to electrostatic precipitator #5 and then to the 1250' chimney and the weak gas flue is ducted to the electrostatic precipitator #2 and to the 1250' chimney.

The normal Pierce-Smith converters (35' long and 13' in diameter) have loose fitting hoods which are necessary to allow entry of sufficient air to cool the hot (2300°F) gases from the converters to prevent burning of the hoods. Off gases from these converters, #2, 4, 6, 7, 8, 9 and 10 are ducted through electrostatic precipitator #2 to the

1250' chimney whilst the remaining converters (#11,12,13, 14 and 15) are ducted through electrostatic precipitator #3 (see Figure 2) to the 1250' chimney. Hence during blowing operations when the converter opening is underneath the hood (conventional or water cooled), the bulk of the process off gas is vented through electrostatic precipitator #5, 3 or 2 (depending on the converter) to the 1250' chimney.

Fugitive emissions i.e. all emissions not vented to the 1250' chimney, from the nickel converters, are vented through 9 natural draft monitors (19' x 24' vents). The location of the monitors is marked on Figure 2.. Flue dust from electrostatic precipitator #2 is recycled to the reverberatory furnaces, and flue dust from electrostatic precipitator #3 is recycled to the copper flash furnace.

#### Copper Concentrate Circuit

The copper circuit feed, copper concentrate and sand, is dried in two natural gas fired fluid bed driers. The off gas containing the dried particulate is cleaned and emitted to the 1250' stack via electrostatic precipitator #3 and the dried feed is ducted to a storage bin. The stored feed and flue dust are injected, essentially horizontally, into the copper flash furnace in an oxygen stream in the furnace main burners. The iron and sulphur oxidize, generating heat to melt the copper and nickel sulphides, thus the concentrate is made to roast and smelt in a single stage, autogenously. The iron oxide reacts with the silica to form a complex iron silicate complex which forms the slag. The slag is skimmed off in pots and dumped in the slag dump. The matte is

tapped off the bottom of the furnace and charged to the copper converters which are similar to the Pierce-Smith nickel converters in design.

Gas from the matte and slag pouring operations is exhausted through forced draft vents to the atmosphere and fugitive gas emissions from the area are released to atmosphere through large vents. Off gas from the flash furnace process, consisting of approximately 80% sulphur dioxide, is air cooled in a settling chamber, scrubbed in a splash tower, treated in gas scrubbers and finally treated in a mist electrostatic precipitator. The off gas is then drawn through a fan and ducted to the C.I.L. liquefaction plant, producing liquified  $\text{SO}_2$ . The gas returned from the C.I.L. liquefaction plant or bypass gas is vented to electrostatic precipitator #3 and then to the 1250' chimney. Flue dust from the electrostatic precipitator #3 is mixed with the charge to the copperflash furnace.

As indicated, the matte from the flash furnace is charged to the copper converters. These converters are blown with oxygen enriched air to reduce the sulphur content and oxidize the iron, which combines with silica to form a slag. Slag from the copper converters can be charged to the copper flash furnace or the nickel converters or the nickel reverberatory furnaces. The converter product, blister copper, is approximately 98% copper. The blister copper is feedstock for the copper refinery and is shipped there in hot metal cars.

During blowing operations, when the converter opening is underneath the hood, the bulk of the process off gas is



vented through electrostatic precipitator #3 to the 1250' chimney (see Figure 2). Fugitive emissions, i.e. all emissions not vented to the 1250' chimney, from the copper converters are exhausted via roof monitors (about 19' x 24' vents) to atmosphere as noted in Figure 2.

#### Matte Processing

The nickel-copper-sulphur ingots from the cooling mould are crushed by a ten ton pile driver (see Figure 4). The chunks are fed to a jaw crusher in series with two gyratory-type crushers that break the material into minus 1/2 inch diameter.

The dust from the crusher and conveyers is drawn off to baghouses (2) approved by the Ministry of the Environment and the cleaned air is vented to atmosphere. The casting building has 10 roof vents which individually are not considered to be significant sources of atmospheric emissions.

Crushed matte from the casting building is transported by conveyor to the separation building where the material is separated into a metallic fraction (Nickel Refinery feedstock) a copper concentrate (recycled to the copper concentrate circuit), and two nickel concentrate fractions (pumped to the fluid bed roaster building), in a complex interrelated series of wet processes including crushing, grinding, flotation, magnetic separation, thickening, and centrifugal classification.

Dust emission points in the process such as conveyor transfer points, storage bin loadouts, etc., have dust collection and treatment systems approved by the Ministry of the Environment (see Table I). In addition, certain gaseous process emissions

such as ball mill exhausts are treated in approved Ministry of the Environment control systems (see Table I).

Building ventilation is provided by five roof fans and these are not considered individually to be significant sources of contaminant emissions.

The feedstocks and feed circuits for the four fluid bed roasters are all essentially the same. Slurry from the separation building is pumped to pulp storage tanks, to a constant head tank and dewatered on a disc filter. The exhaust gases from the disc filters pass through a cyclone before being emitted to atmosphere. The filter cake (about 8% moisture) is pelletized on pelletizing discs which are vented to a baghouse and then to the atmosphere. The nickel sulphide pellets are oxidized in one of the four fluid bed roasters at 2000 to 2200°F, each with a capacity of about 300 TPD. The fluidized air is enriched with oxygen to increase throughput and reduce fuel requirements.

Calcine is drawn off the fluid bed roasters in an air lift. On two roasters, calcine is withdrawn to fluidized coolers, which quench the calcine to about 200°F. The other two roasters are equipped with reroasters to further reduce the sulphur content, then the product is cooled in fluidized coolers. The off gas from the reroasters is ducted back to the fluid bed roaster and off gases from the fluidized coolers are ducted to precipitators along with off gases from the fluid bed roasters (after treatment via impingement

plate and cyclone for dust removal). This treated process gas is discharged to the atmosphere via the 1250' chimney.

Generally the lowest purity calcine product is used as feed for the Port Colborne Nickel Refinery, a higher purity calcine product is used as feed for the Clydach Refinery and the highest purity calcine product is either marketed as Sinter 75 or used as feed for the Chlorination Reduction Plant which further treats the material to provide a variety of marketable nickel products.

The various products are stored in bins (8) with dust collection systems and baghouses (3) approved by the Ministry of the Environment, to contain dust emissions from the conveyors, packaging, bulk loadout and transfer areas.

Fugitive emissions from the roaster area are exhausted through roof monitors above the fluid bed roasters to atmosphere. These emissions by themselves are not considered to be a significant source of contaminants.

## ii) NICKEL REFINERY

The Nickel Refinery, designed to produce 100 million pounds of nickel pellets and 25 million pounds of nickel powders per year was completed in 1973 at a cost of \$140 million. The refining process can be broken down into two sections; the Converter Plant and the Inco Pressure Carbonyl (IPC) Plant. The various atmospheric emission sources at the nickel refinery are detailed in Table II and located on a plant diagram in Figure 5. Figure 6 is a process schematic diagram.

## Converter Plant

The feed preparation in the converter plant includes the receiving and handling of Clydach Residue, primary metallic concentrates (a portion briquetted with flue dust), coke and other raw materials.

The feedstocks are charged to one of two fifty ton capacity top blown rotary converters with the hooding in place, except for the batch charging of Clydach Residue and briquetted flue dust-primary metallics which are charged with the hooding open. These converters typically operate on a three phase, 4 3/4 hour batch cycle - 1 3/4 hour charge/melt - 1 1/4 hour blow and 1 1/2 hour reduction. The finished hot metal is transferred to a teeming ladle, granulated using high pressure water jets, dried and conveyed to the I.P.C. Plant.

During the converter process cycle, off gases are collected in a hood over the converter, cooled by water addition in an evaporation chamber passed through an electrostatic precipitator and fan and ducted to the I.O.R.P. 637' chimney (see Figure 7). When the hoods are not in place, (sampling, batch charging or pouring operation) off gases vent to atmosphere through three roof vents.

Each of the feed handling/storage systems have a fugitive-dust collection/baghouse treatment system and baghouses are also used on fugitive dust collection systems serving the coke hopper area, charge hopper area, the briquette storage area and charging elevators.

The teeming ladle preheater (5) exhaust gas and the exhaust

gases from the gas fired kiln dryer are cleaned in a scrubber and vented to atmosphere. The granulation sluice is vented directly to atmosphere via a 49" diameter stack.

#### I.P.C. Plant

The granulated feedstock from the converter plant (75% Ni, 17% Cu, 2.3% Fe, 0.8% Co, about 5% S and precious metals 0.1%) is charged to one of three 150 ton capacity rotating pressure carbonylation reactors. The charge ports are located in the middle of the reactor and are covered by a dust hood. During charging, inert gas and entrained dust are vented to atmosphere through one of two identical baghouses.

The dry metallic granules are batch reacted (42 hour cycle) with carbon monoxide at temperatures up to 350°F and pressures up to 1000 psi. Nickel and some iron combine with the carbon monoxide to form volatile carbonyls.



Copper, cobalt, precious metals and impurities remain in the residue which is recovered, ground in a rod mill and pumped as a slurry to the Copper Refinery. Crude nickel carbonyl vapour is condensed at 0°F in a condenser and stored.

The crude liquid carbonyl is purified in 2 parallel distillation columns fifty feet in height. The nickel and iron carbonyl is separated (boiling point of  $\text{Ni}(\text{CO})_4$  is 180°F and  $\text{Fe}(\text{CO})_5$  is 217°F) in the distillation tower into two fractions, a nickel carbonyl vapour and an iron-nickel carbonyl liquid. The nickel carbonyl vapour leaves the top of the column, and

enters a partial condenser. The condensed portion of the nickel carbonyl is broken into two streams, one is reflux for the distillation column, the other is stored. The vapour portion (about 80%) of the inlet  $\text{Ni}(\text{CO})_4$  goes to the pellet decomposers (18 units) where the nickel carbonyl is thermally decomposed. Released carbon monoxide is recycled to process through 3 baghouses (2 additional baghouses on standby).

The purified liquid nickel carbonyl (stored portion) is pumped from storage, vapourized and decomposed in electrically heated powder decomposers (8 units). The nickel powder (99.8% Ni) is stored in bins. The carbon monoxide, released from decomposing the carbonyl passes through a baghouse, (one per unit) pass through a second communal baghouse (1 additional on standby) and is recycled to process.

The liquid bottoms (iron nickel carbonyl) from the distillation column are vapourized and decomposed in electrically heated powder decomposers (2 units). The carbon monoxide, released from the decomposed carbonyl passes through two baghouses in series (for each decomposer) and is recycled. The ferro-nickel powder (70% Fe, 30% Ni) is stored.

The liberated carbon monoxide gas from the decomposers is compressed and sent to storage for re-use. Make up carbon monoxide, about 7000 cubic feet per hour, is produced through the decomposition of natural gas and is purified using scrubbers, absorbers, strippers and alumina desiccant.

The carbonyl process vents and the carbon monoxide vents are routed to an incinerator/flare system. The gas from the

collector system passes through an incinerator which raises the temperature of the gas to 1600°F, (residence time of approximately 1.1 seconds). The combusted gas is then cooled by water addition to about 400°F before entering a baghouse which removes entrained dust. The gas passes from the baghouse through a fan and enters the 3' diameter 150' flare stack. In the event that the incinerator and baghouse system must be bypassed, there is a vapor burning vent flare stack which serves as a backup to the primary system to combust any residual carbonyl or carbon monoxide and finally a vapor burning relief flare stack which handles rupture disc exhausts etc., as well as any overloads on the incinerator and vent flare stack. Carbonyl contaminated liquid effluents are stored and are also combusted in the incinerator baghouse system.

Nickel powder from 4 decomposers is packaged in the decomposer area. All other packaging takes place in the packaging and warehouse area. The nickel powder, ferro-nickel powder and nickel pellets are each stored in dual overhead bins in the packing and warehouse section. The powder lines (2) converge into a single lid-dispensing, weighing, crimping and stamping system. There are two baghouse systems for dust removal in the packaging department. The pellet packaging system is similar but is not equipped with a baghouse.

All liquid wastes from the nickel refinery are adequately treated and discharged via a pond system to Kelly Lake. Wastes include cooling tower blowdown, yard runoff, wash-up wastes and granulation system overflow.

### iii) IRON ORE RECOVERY PLANT

The Iron Ore Recovery Plant operation is divided into 4 sections, each contained in a separate building with connecting flows. The four sections are the Roaster-Kiln, Leaching, Recovery and the Pellet Building. C.I.L. operates 3 acid plants, supplied with  $\text{SO}_2$  from the roaster-kiln operation as part of the complex. The various atmospheric emission sources are listed in Table III and located on a building layout in Figure 8. All liquid process wastes, surface runoff and sewer wastes (collected in a holding pond) are routed to a thickener station and pumped to tailings.

#### Roaster-Kiln Section

Iron ore concentrate (pyrrhotite) is pumped from the Copper Cliff concentrator to the Iron Ore Recovery Plant, a distance of approximately 4 miles. The feed (58% Fe, 35.8% S - ranges 34.5% to 36.5%, 2.0% Si, 0.9% Ni and 0.05% Cu) is thickened to a 70-75% solids slurry, pumped to a feed tank and then pumped to the fluid bed roasters. There are 6 fluid bed roaster-reduction kiln circuits in the Roaster-Kiln building. Each fluid bed roaster has two parallel circuits, one for calcine recirculation and one for production. Each of the two circuits has a boiler, a cyclone and the off gases from these circuits are treated in an electrostatic precipitator and either ducted to the 637' chimney or to the C.I.L. acid plants for the manufacture of sulphuric acid. The roasters have a nominal capacity of 500 TPD of pyrrhotite feed. Figure 9 is a diagram of the fluid bed roaster-kiln system and Figure 10 is a diagram of the flue system.



The product calcine is collected from the production off-gas boiler/cyclone system and along with electrostatic precipitator dust is fed to the reduction kiln.

The draft in the fluid bed roaster - acid plant flue system is maintained by C.I.L. such that, at the outlet of the electrostatic precipitators, there is draft of minus 5" W.G. If the vacuum decreases to between 0 and minus 2" W.G., the bypass valve to the 637' stack automatically opens. Fluid bed roasters 1 through 4 are connected by a common flue to the C.I.L. acid plants and roasters 5 and 6 have their own separate flues as shown in Figure 10.

There are 7 natural draft ventilators over the roaster-main boiler-flue system, one over each roaster unit. Ventilators 1, 2, 3, 4 and 7 are 83' x 11' and ventilators 5 and 6 are 21' x 15'. These ventilators by themselves are not considered to be significant sources of atmospheric contaminants.

Calcine from the roasters is fed into cylindrical rotating kilns. The kiln is used to transform the hematite to magnetite and transform the nickel into leachable forms (nickel alloy and nickel sulphides). The feed end of the kiln is heated to about 1600°F by a natural gas burner. Combustion air is preheated to approximately 700°F by a heat exchange with exhaust gases.

The kiln is approximately 180' long with an inside diameter of 13'. The kiln has a 3% slope and rotates at about 0.6 RPM to help move the calcine through the kiln. Lifters keep the charge cascading and promote contact with the reducing gases ( $\text{CO}_2$ :  $\text{CO}$  = 2.5:1). Total retention time for the kiln is about 5 hours.

The kiln off gases pass through a shell and tube heat exchanger and a cyclone. The off gases then pass through a scrubber. There are three scrubbers for the six kilns of which two are in operation. A portion of the off gas can be ducted to a CO<sub>2</sub> recovery system and to the atmosphere or all of the off gas can be ducted to an after-burner where the residual combustibles are consumed. There are four after-burners (typical 2000°F) vented to a breeching where dilution air is modulated through a damper to maintain a 900-1000°F breeching temperature. The diluted gases are then vented to the atmosphere through the 637' stack.

The reduced calcine from the kiln is quenched and passed through a regrind circuit. The non-magnetic fraction is recycled or wasted and the magnetic fraction is repulped with ammoniacal leaching waste water and pumped to the Leach Building.

All liquid wastes from the roaster-kiln building including feed thickener overflow, wash-up, and boiler wastes are recycled or discharged to the 35' thickener station for re-pumping to the Copper Cliff central tailings area.

Six ventilators vent the reduction kiln area; monitors for kilns #1, 2 and 3 are equipped with fans whereas monitors for kilns 4, 5 and 7 are natural draft. Heat from the Unax Coolers (8' x 25') is also discharged directly to the natural environment.

## LEACH BUILDING

The calcine slurry is leached at essentially atmospheric pressure in aerated ammoniacal ammonium carbonate solution for the recovery of copper, nickel, cobalt and precious metals (see Figure 11). The operation is a counter-current six stage process - five leaching stages and one grinding stage. Each stage consists of a series of concurrent agitated vessels separated from each other stage by magnetic separators. Dilute ammoniacal solution is added in the fifth leaching stage whereas concentrated leach solution is added for make-up in the 3rd, 2nd and 1st leach stages.

Pregnant solution (i.e. the solution containing high concentrations of the leached metals) is removed to the recovery process from the first stage magnetic separator. The leached magnetite from the fifth stage leach magnetic separator is washed counter-currently in a series of magnetic separators with barren solution, and is repulped from the final stage using pellet plant recycled water for pumping to the pellet plant. Wash water is recycled to ammonia recovery.

All exhaust gases from the aerated leach tanks, ball mill and separators are vented to atmosphere via an absorber-separator-scrubber system for ammonia recovery. The system has two fans with one used for backup service. The ammonia laden solution from the separator is pumped to ammonia recovery (see Recovery Building Description) and the off gas from the scrubber is vented to atmosphere.

There are 25 roof fans in the leaching building to remove fugitive emissions. The steam drier for the copper-nickel sulphides is also in the leaching building from which the exhaust gases are scrubbed and vented to the atmosphere.

All process waste water from the leaching building is discharged to the 35' thickener station via the roaster-kiln building.

### Recovery Building

The pregnant solution (see Figure 12) from the leaching building is preheated in a heat exchanger and pumped to copper removal tanks. In these tanks the pregnant solution, sulphide reagent, soda ash and steam are mechanically agitated to precipitate most of the copper which is recovered and shipped to the Copper Cliff Smelter.

The solution from copper removal stage goes to first stage nickel precipitation. Ammonia and carbon monoxide are stripped from the solution by steam in a stripping column. The bottom solution is pumped to one of the first stage distillation lines (three) and the distillate is recycled to the ammonia recovery system. Each distillation line consists of up to six kettles in a series followed by a flash tank. The solution is heated and agitated by counter-current steam. The steam strips the remaining ammonia and the major portion of carbon dioxide and precipitates nickel as a basic carbonate.

The flash tank removes entrained gas which is vented to the atmosphere or used for building heat. The slurry is then pumped to the first stage nickel thickener. The overflow from the thickener is filtered in a pressure filter, the filtrate is returned to leaching as barren solution for wash water, repulp water or is discharged to the 35' thickener and the filter cake is recycled to the first stage nickel thickener.

The nickel precipitate from the first stage nickel thickener is redissolved and mixed with ammonium carbonate solution, soda ash, sulphide reagent and steam in the second stage copper removal tanks (3 in series). The solution is then pumped to the second stage copper thickener. The slurry from the bottom of the thickener is returned to the first stage copper removal tanks.

The overflow from the second stage copper thickener then enters a second nickel precipitation stage, similar to the first stage. A difference in the process does exist in that the second stage precipitation kettles have individual steam inputs and the off gas from the intermediate flash tank is vented to ammonia absorption.

The overflow from the second stage nickel thickener enters a further train of 5 kettles. Steam passes countercurrent to the pregnant solution to remove any remaining ammonia and carbon dioxide and also to precipitate any remaining nickel and cobalt. The off gases from these kettles enters the second stage stripping tower.

The precipitate from the kettle train passes through a final flash tank and is recycled pumped to the first stage nickel thickener. The off gas from the flash tank is vented to atmosphere or building heat.

The precipitate from the second stage nickel thickener is further purified, dried, and calcined in a kiln to nickel oxide and packaged for shipment.

The off gas from the purification stage belt filters is vented to atmosphere and the kiln off gas and drier off gas are treated in separate scrubbers and vented to the atmosphere. The nickel oxide is conveyed to blending and shipping by an airslide conveyor. The airslide conveyor and nickel oxide transfer sites are vented through a baghouse to the atmosphere.

The ammonia-carbon dioxide recovery-make up system (see Figure 13) consists of 4 separate absorber systems with a secondary absorber system to collect off gases from these four systems. The ammonia and carbon dioxide from the first stage stripping tower and second stage stripping tower enter parallel absorber systems, consisting of two absorber columns and two separators. Make-up ammonia and carbon dioxide are added to these absorber systems. There is a reflux stream from the first and second separators to the first absorber column. Concentrated and dilute ammonical carbonate solution are drawn from the first and second separators respectively for leaching. Off gas from the first separator enters the second absorber column and off gas from the second separator is further treated in the secondary absorber system and then is vented via a fan to the atmosphere.

As noted under "Leach Building" the bottoms from the separator in the leach gas recovery system are pumped to a storage tank. The ammonical solution passes through a heat exchanger and the heated solution enters an ammonia recovery stripper. The steam stripped bottoms are cooled in a heat exchanger and pumped to the first stage nickel thickener. The stripped gas enters the leach gas absorber column and the gas from the absorber column enters a further separator. The bottoms, a concentrated ammonical carbonate stream is pumped back to the absorber for reflux and a stream is pumped to the concentrate storage tank. The off gas enters a second leach gas absorber along with leaching wash water. The dilute ammonical carbonate solution is pumped to a storage tank from the second leach gas absorber separator and the off gases from the separator are treated in the secondary gas cleaning absorbers before being vented to atmosphere.

The off gas from the intermediate flash tank and a stream from the second stage reflux tank are fed with make up ammonia and carbon dioxide to further absorbers and separators. Vermillion River water is added to the second absorber. Off gas from the second separator is vented to the secondary gas cleaning absorbers. The absorber solution from the second separator is recycled to the first absorber tower. The concentrated ammonical carbonate solution from the first separator is pumped to the second stage recovery process.

There are 16 roof fan vents in the Recovery building to remove fugitive emissions.

Liquid effluents from the Recovery building, including recovery barren solution and leach gas barren solution are recycled to the 35' thickener station and wash-up wastes are discharged to the surface holding pond which is also pumped to the 35' thickener station.

#### Pellet Plant

Leached magnetite from the wash section of the leaching process is repulped using recovery barren solution and pumped to magnetic separators (4 magnetic separators in parallel). The non-magnetic stream is recycled via the process water system to the 35' thickener. The magnetic stream (65% solids) is stored, pumped from storage to disc filters (filtrate is fed to the ball mill) and the filter cake containing about 15% moisture is stored in rotary bin feeders. Lime and Bentonite (aluminum silicate) are added to the filter cake which is discharged to a belt mixer and then to pelletizing discs which form 5/8" green balls.

The fragile green balls are conveyed on roller conveyors to travelling grate sinter machines. Fines passing through the roller conveyors are returned to the balling disc.

The green balls are protected by a layer of iron ore pellets on the bottom of the travelling grate. The travelling grate machines (2 in parallel) have three zones; drying, firing and cooling. The gradual heating of the green pellets prevents spalling, and breaking of partially fired pellets by flash oxidation and sudden temperature rise. The pellets



are dried at approximately 550°F, enter the firing zone with temperatures up to 2450°F and then the pellets are cooled in a cooling zone. The air used in the cooling zone is used as combustion air in the firing zone and some of the air from the firing zone is used with tempering air in the drying zone. The air is drawn through the charge in each of the three zones by fans. Gases from both the firing zone and drying zone are drawn off to 150' stacks and exhausted to atmosphere just above the pellet building roof. There is also an air bleed from the drying zones which is exhausted out the side of the pellet building.

The iron ore pellets are dropped off the travelling grate sinter machines into a chute and sent to screening. Exhaust gas from each drop off zone is scrubbed and vented to the atmosphere. The pellets are screened to eliminate chips and fines which are recycled to the fines ball mill. The exhaust air from the screening is scrubbed and vented to the atmosphere. A stream of pellets is returned to the travelling grate machines (approximately 20% of the product). The train car loadout area is vented to a scrubber and exhausted to the atmosphere. Scrubber water is obtained from the thickener and is also returned to the thickener. There are 7 louvered cooling vents (15' x 20') on the roof of the pellet building, 5 directly over #2 sinter machine and 2 over #1 sinter machine.

Effluent from the pellet plant is pumped to the 35' thickener and then to the tailings area.

## iv) CANADIAN INDUSTRIES LIMITED

The three C.I.L. acid plants can draw process gases from any of the 6 fluid bed roasters. Roasters 1-4 are connected to C.I.L. by a common flue and roasters 5 and 6 have their own separate flues to C.I.L. All plants (total acid production capacity about 3000 TPD at 100%  $H_2SO_4$ ) are essentially the same in operation and all vent absorber off gas to the I.O.R.P. 637' chimney.

## No. 4 Acid Plant

Fluid bed roaster off gas enters the Peabody Scrubber of #4 acid plant. The inlet grain loading is about 0.25 grains/ft<sup>3</sup> and the scrubber removes 98 to 99% of the particulate greater than 5 microns. The gas is further cleaned by passing through wet electrostatic precipitators.

Dilution air is stripped of moisture by 93% sulphuric acid in a drying tower, then blended with the off gas from the precipitators and moisture is again removed in a further drying tower with 93% sulphuric acid. A demister is used on the top of the drying tower to remove entrained droplets.

The gas then passes through the main blower and enters a series of heat exchangers to bring the gas temperature to about 440°C. The gas passes through a new first pass converter, wherein the temperature rises to about 600°C, by the exothermic oxidation of  $SO_2$  to  $SO_3$ . There are 3 passes through the catalytic beds with quenching to maintain temperatures of about 440°C.

The  $\text{SO}_3$  is cooled to about  $200^\circ\text{C}$  in an air cooled heat exchanger and recovered using concentrated sulphuric acid in an absorption tower equipped with a demister to remove acid mists.

The off gas from the absorbing tower is then vented to the 637' stack.

For start-ups, the process  $\text{SO}_2$  off gas is heated in preheaters to about  $400^\circ\text{C}$  till the exothermic reaction generates enough heat to be self-sustaining.

## IMPACT OF CONTAMINANTS

### (i) SULPHUR DIOXIDE

#### (a) Emissions

Major sources of sulphur dioxide include the Iron Ore Recovery Plant 637' chimney, Smelter 1250' chimney and Smelter low level emissions i.e. building ventilation and/or short stack emissions.

As indicated in the process description, the bulk of the Smelter atmospheric sulphur dioxide emissions are exhausted via the 1250' chimney and include process gases from the Herreshoff roasters, reverberatory furnaces, converters, copper flash furnace and fluid bed roasters. The quantity of emissions varies depending on processing rate. For sulphur dioxide, based on a nominal emission of 3600 tons per day, the current approximate contribution of the various processes are outlined in Table IV. The actual total emissions from the smelter based on metallurgical mass balancing techniques for the year 1960 and for the period from 1970 to 1977, are outlined in Table V. It is noted that emissions of sulphur dioxide have been substantially reduced since 1960 and during the period 1970 to 1977. This reduction has been achieved in large part through rejection of pyrrhotite from the smelter feed.

Quantitative data are not available to prorate total smelter emissions into the 1250' chimney and low level contributions. On the basis of preliminary test work, low level emissions

are qualitatively estimated to be approximately 4% of smelter emissions i.e. approximately 150 tons per day at a nominal emission rate for the smelter of 3600 tons per day. It must be noted that this value is a qualitative estimate while the actual emission level will vary significantly as a function of total emission, depending on maintenance schedules, processing mode, etc. Information on the relative magnitude of the various low level contributors is not available, however, intuitively it is suggested that the major contributing vents are probably the converter vents and the matte tunnel and matte pouring / slag skimming system powered ventilators.

The only significant emission of sulphur dioxide from the Iron Ore Recovery Plant complex is from the 637' chimney. Contributions to the 637' chimney are from the Nickel Refinery, CIL Acid Plant tail gases (plants #2, 3, 4), Iron Ore Recovery Plant kiln gas and exhaust gas from the fluid bed roasters as a result of butterfly damper trips. Damper trips are due to pressure control upsets in the roaster - acid plant gas handling system. These emissions are quantified based on daily mass balances ( $\pm$  40 tons per day). The actual emissions from the plant for 1960 and for the period 1970 to 1977 are outlined in Table VI.

Variation in emission levels at the Iron Ore Recovery Plant during an actual day depend significantly on processing/butterfly damper problems, conversion efficiency of the CIL Acid Plants and mode of operation of the Nickel Refinery TBRC converters. Sources of this variation are qualitatively presented in Table VII, on a tons per hour basis, with a summary presented in Table VIII.

It is recognized that it is difficult to correlate total emissions from the 637' chimney with process variations on an hour by hour basis, due to the variability of the processes contributing to these emissions. For this reason, Tables VII and VIII are provided to offer benchmark levels which might be used to assess actual variations in total emission levels and hence ground level concentrations of sulphur dioxide. With reference to the above noted data, it is obvious that under steady state conditions, the acid plants tail gas contribute significantly to the total emissions from the 637' chimney, whereas for short time intervals, it is obvious that both the Nickel Refinery and butterfly damper trips can contribute significantly to instantaneous or short term emission rates.

(b) Calculated Ground Level Concentrations

As provided by Regulation 15 under The Environmental Protection Act, 1971 the concentration of a contaminant at a point of impingement may be calculated in accordance with the appendix attached thereto. Specifically, maximum ground level concentrations have been calculated for sulphur dioxide for the Iron Ore Recovery Plant 637' chimney, the Smelter 1250' chimney and for the Smelter low level emissions, as individual sources as outlined below.

| <u>Source</u>                           | <u>Calculation Procedure</u> | <u>Comments</u>                                                                                                                                            |
|-----------------------------------------|------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Smelter 1250' chimney                   | Appendix<br>Clause 2C        | No comment                                                                                                                                                 |
| Smelter low level emission              | Appendix<br>Clause 2B        | No comment                                                                                                                                                 |
| Iron Ore Recovery Plant<br>637' chimney | Appendix<br>Clause 2C        | Notwithstanding note 4, Clause 2C, credit is provided for stack exit velocity for wind speeds from 2.235 metres/second to 1 1/2 times stack exit velocity. |

These calculations are summarized in Tables IX and X. With reference to Table IX it is noted, that for the conditions of the calculations, the calculated ground level concentrations of sulphur dioxide from the 1250' chimney emissions comply with standards in Regulation 15 whilst the calculated ground level concentrations for the low level emissions comply only at a distance in excess of 3,000 meters. They do not comply at nearer receptors (see Figure 1) such as Highway 17 (1,000 meters) and residential areas in Copper Cliff (400 to 700 meters).

Similarly with reference to Table X, for the conditions of the calculations and a steady state emission of 250 tons per day of sulphur dioxide, the calculated ground level concentrations for the Iron Ore Recovery Plant comply with the standards in Regulation 15. However, a steady state emission of sulphur dioxide of 250 tons per day is equivalent to approximately an hourly emission of 10.4 tons, and with reference to Table VIII, it is noted that under different hypothetical situations, emissions on an hourly basis may range from 6.6 tons to 27.5 tons. These levels will be expected to occasionally

occur, since there is at present no attempt to schedule nickel refinery emissions in relation to conditions occurring at the Iron Ore Recovery Plant and the CIL Acid Plants, and because upset conditions related to acid plant conversion efficiencies and butterfly damper trips are not totally predictable. For example, during conditions when the Nickel Refinery is contributing maximum emissions i.e. one converter blowing and one converter on reduction, either a drop in total acid plant conversion efficiency to less than 92.5% or a frequency of butterfly trips totalling greater than 13%, or a combination of the two, would contribute sufficient emissions to produce a calculated ground level concentration for sulphur dioxide in excess of the standards in Regulation 15. As a second example, with acid plants achieving an efficiency of 94%, one damper equivalent open during the hour (CIL running - assume half of gas to stack) at the Iron Ore Recovery Plant, and the Nickel Refinery either blowing or reducing on one converter (second converter idle) sufficient emissions would be exhausted to produce a calculated ground level concentration for sulphur dioxide in excess of Regulation 15.

The foregoing is to some extent an exercise in hypothetical situations and as such should not be considered a rigorous analysis of emissions levels. However, it is a fact that the acid plants are occasionally run for short periods of time at less than 94% conversion efficiency (1977 average estimated by CIL to be about 92% - 93%), it is a fact that the Nickel Refinery while not the largest contributor, on a tons per day basis, does contribute significant emissions



during certain phases of the converter operation and lastly it is a fact that occasionally, for numerous reasons, the Iron Ore Recovery Plant can experience a significant percentage of butterfly damper trips or openings during any one hour period.

The major Inco sulphur dioxide sources i.e. the Iron Ore Recovery Plant and the Smelter are located within 5 km of each other and because of this closeness, the impact of their emissions could be expected to overlap and magnify each other, especially when the wind is such that the major emission sources are in line i.e. northeast or southwest winds. For illustrative purposes, the relative impact of the plumes with a southwest wind is depicted in Figure 14 for C stability conditions with the wind speed at 7 1/2 meters per second. As might be expected, it is noted that under these conditions, the overlapping impact does exist and interferes with the interpretation of ground level monitoring data, as it relates to individual sources. Figure 14 was provided for illustrative purposes only, since in practice the modelling is extremely complex i.e. for the smelter 1250' chimney, the greatest dispersion problems occur with a clear sky and near calm wind velocities and at present there is not adequate modelling capability to predict maximum concentrations from low level sources under these near calm conditions, especially in view of the complexity of the local terrain, etc.

specific meteorological conditions at the time. That is, each source has a capability of affecting these stations. Similarly, with respect to the hours noted greater than 0.25 ppm it is the author's opinion that while those hours recorded at the Ash Street and Lockerby stations may be significantly influenced by either the Iron Ore Recovery Plant 637' chimney or smelter low level emissions, all recorded hours at other stations are predominantly due to the smelter 1250' chimney emissions.

The Industrial Abatement Branch in Sudbury received 82 complaints concerning SO<sub>2</sub> in 1977, with respect to the surveyed Inco operations. The bulk of the complaints were during the months of May, June, July and August and were related to short periods of high concentrations.

#### (ii) PARTICULATE

Potentially significant sources of particulate emission from the surveyed sources include the Nickel Refinery building emissions i.e. all emissions not vented via the Iron Ore Recovery Plant 637' chimney, the 637' chimney and Pellet Plant chimneys at the Iron Ore Recovery Plant Complex and low level and 1250' chimney emissions from the Smelter.

Process gases exhausted via the smelter 1250' chimney are treated in high efficiency electrostatic precipitators (5 units, one for each major flue) for particulate removal as noted in the process description. However, these gases still constitute a significant source of particulate and sulphuric acid. With respect to this source, as noted in

(c) Measurements/Effects of Ground Level Concentrations

During 1977 the Ministry of the Environment operated 17 sulphur dioxide monitoring stations in the Sudbury airshed as depicted in Figure 15. Due to the location of the stations, i.e. to monitor airshed quality in relation to all sulphur dioxide sources, and due to the close geographical proximity of the Inco sources, the data do not provide for easy interpretation in a source - receptor sense. Thus at the outset, it is acknowledged that difficulties arise in interpreting the impact of the Iron Ore Recovery Plant versus the smelter 1250' chimney versus the smelter low level emission impact, especially for the close in stations (except under unusual conditions). Further, for some stations, it is impossible to determine whether the recorded concentrations for sulphur dioxide were due to Inco sources surveyed or to other industrial sources in the Sudbury airshed.

Excluding all data which could not be reasonably attributed to the surveyed Inco Limited sources, sulphur dioxide monitoring data for 1977, for hours in excess of 0.25 ppm and 0.5 ppm, is summarized in Table XI. For those hours noted greater than 0.5 ppm, based on the theoretical ground level concentration calculations presented and personal observation, it is the author's opinion that it is most likely that those hours recorded at the Lake Penage, Hanmer, Rayside, Garson and New Sudbury stations are attributable predominantly to the 1250' chimney emissions while those recorded at the Lockerby and Ash Street stations may have been attributed by any and/or all of the three sources surveyed, depending on

Table XII, while the loading of total particulate (and individual elements) and sulphuric acid varies considerably, even if the maximum emission numbers are used for calculation purposes, using procedures outlined in Regulation 15, the ground level concentrations so calculated for nickel, copper, acid and total particulate, etc. comply with Regulation 15.

Gases emitted via low level/building vents from the smelter could be a source of significant particulate as is indicated in the preliminary tests conducted on typical copper and nickel converter vents in 1974 (summarized in Table XIII). However, emission loading data on the other low level sources are not available and the converter vent data are considered to be too preliminary to be used for quantitative assessment purposes. There is an obvious data need in this area, so as to allow assessment of the significance of these emissions with respect to environmental standards.

The bulk of the process gas emissions at the Nickel Refinery are associated with the operation of the converters and are emitted, after treatment in electrostatic precipitators for particulate removal, via the Iron Ore Recovery Plant 637' chimney, along with Iron Ore Recovery Plant main flue emissions and CIL Acid Plant tail gas emissions. Information available on the various contributions to the 637' chimney, based on 1976 stack tests, are summarized in Table XIV, along with ground level concentrations calculated in accordance with procedures outlined in Regulation 15 (with the specification that  $V_s$  (slack velocity) equal 5 meter per second for  $V$  (wind speed) less than  $1\frac{1}{2} V_s$ ). With reference to Table XIV, it is noted that on a calculation basis, all parameters

comply with standards in Regulation 15, except nickel which is predominantly contributed by the Nickel Refinery, with the highest loadings occurring during the converter charge phase. Further, it should be noted that for a two converter operation, any overlap of a charge phase on one converter with any phase on the second converter would accentuate the magnitude of the calculated nickel ground level concentrations.

During 1977, Inco Limited staff conducted a total of 103 routine emission tests in the Nickel Refinery flue to the Iron Ore Recovery Plant. The results of these tests with ground level concentrations calculated as provided in Regulation 15 are summarized in Table XV. With reference to this table, it is noted that using average loadings, for either a one or two converter operation, calculated ground level concentrations are in compliance with Regulation 15. However, using a 95% confidence level for loading it is noted that any combination of charge and any other phase of operation in a two converter operation would result in calculated ground level concentrations in excess of Regulation 15, for nickel.

While the converter process in the Nickel Refinery is the largest single source of emissions, many other operations in the Nickel Refinery process, particularly solids handling, conveying, and packaging give rise to atmospheric emissions as a result of the various dust collection, containment, treatment and discharge systems. These systems, as detailed in the process description, give rise to particulate emissions which may have high nickel proportions. However, insufficient data are available to allow an assessment of the nature and

quantity of these emissions and hence an assessment of compliance/non-compliance with standards in Regulation 15.

The only known source of significant particulate emissions from the Iron Ore Recovery Plant (other than the 637' chimney) is the particulate emitted from the Pellet Plant with the process gases exhausted from the sinter machines (as noted in process description) via two stacks located on the south end of the Pellet Plant. This emission of particulate, which has been roughly estimated at 3 tons per day, results in a ground level concentration for suspended particulate, calculated in accordance with procedures outlined in Regulation 15, in excess of standards prescribed in Regulation 15. However, due to lack of information relating to particle sizing, compositional analysis and uncertainty with respect to total amount of emission, such a calculated number is considered to be only an order of magnitude. Further information concerning these parameters is required to allow a quantitative determination of compliance/non-compliance with Regulation 15.

The Ministry of the Environment operates hi-vol samplers at Ash Street and Lisgar Street in Sudbury and in Copper Cliff. The results of this program for 1976 and 1977 are summarized in Table XVI, wherein it is noted that total suspended particulate concentrations complied with the annual geometric mean criterion during 1976/77 at these three locations. All analysis at all locations for copper concentrations complied with the air quality criterion and nickel concentrations complied at all locations on all occasions except for one filter in 1976.

(iii) AMMONIA

The Iron Ore Recovery Plant, as outlined in the process description, uses ammonia as a process reagent to facilitate the recovery of nickel from pyrrhotite. While the bulk of the reagent is recycled in process, quantities of ammonia are lost to atmosphere via process emissions and building ventilation and quantities of ammonia are discharged with the liquid process waste from the Iron Ore Recovery Plant to the Copper Cliff central tailings area. Estimates of these losses are compiled on a monthly basis and a summary for 1977 is provided in Table XVII.

The ammonia balance is based on accurate measurements related to chemical makeup, liquid effluent loss, and specific process emission vent losses, with the remaining unaccounted losses included as part of the atmospheric emission loss. If the total average atmospheric emission loss for 1977 is used as an emission loading, using calculation procedures outlined in Regulation 15, one would conclude that ground level concentrations of ammonia in excess of standards in Regulation 15 may be experienced at and beyond the property boundary. However this assumption must be considered qualitative because there is some uncertainty related to the nature of the emitted species and the emission loading for each emission location. These and other factors preclude the drawing of firm supportable conclusions concerning compliance/non-compliance with Regulation 15.

Liquid effluent from the Iron Ore Recovery Plant is pumped to the Copper Cliff central tailings area and is decanted to



Copper Cliff Creek (as tailings area decant) along with other wastes and natural drainage. Copper Cliff Creek discharges to Junction Creek which in turn discharges to the Vermilion River system via Kelly, Mud, Simon and McCharles Lakes. As noted in Table XVIII, liquid effluent from the Iron Ore Recovery Plant contributes a substantial loading of ammonia to this waste handling and disposal system.

Between 1975 and the end of 1977 the Ministry of the Environment conducted a waste water assimilation/modelling study of lower Junction Creek (Junction Creek from confluence with Copper Cliff Creek to confluence with the Vermilion River) which clearly demonstrated that:

1. The majority (85%) of the oxygen demand load presently in the Junction Creek system enters via Copper Cliff Creek. The nitrogenous oxygen demand of Copper Cliff Creek accounts for 95% of its total oxygen demand load.
2. Lower Junction Creek is grossly overloaded with the present loads of oxygen demand materials; carbonaceous and nitrogenous oxygen demand.
3. A reduction in the present total load entering Kelly Lake between 75% and 90% is required to reduce the load leaving Mud Lake to approximately that which Simon and McCharles Lakes are capable of assimilating.

To achieve the required reduction in total oxygen demand entering Kelly Lake, it is required that a reduction of 90% of the nitrogenous oxygen demand in Copper Cliff Creek be



achieved.

(iv) OTHER CONCERNS

For the most part, the above discussions relating to sulphur dioxide and particulate emissions have centered on acceptability/completeness of data base and on compliance/non-compliance with standards detailed in Regulation 15.

These standards detailed in Schedule 1 of Regulation 15 are generally based on odour threshold (ammonia), vegetation damage ( $\text{SO}_2$ ), and health effects ( $\text{SO}_2$  and suspended particulate), however much concern has also been expressed related to other effects. As a simplified overview, these concerns include fate of dispersed pollutants (near effect and long range transport effect), acidic and heavy metal content of rainfall, acidification of lakes and loss of fisheries and finally the global burden related to anthropogenic (man made) sources of pollutants such as sulphur dioxide.

In 1973 the Ministry of the Environment (with input from a number of other agencies) began a scientific investigative program, the Sudbury Environmental Study, to examine in detail these and related concerns. The express purpose of this continuing study is to develop criteria and associated rationale supported by firm scientific evidence for the management of the atmospheric emissions from the mining/smelting industries located in the Sudbury basin. Evidence from this study indicates that while levels of sulphur dioxide and particulate emission have been reduced since the early 1970's, the existing emission levels of these pollutants and

sulphuric acid may not be an acceptable burden to the environment as a whole.

It is anticipated that when the Sudbury Environmental Study has been completed in 1980, data collected will be employed to define reasonable and acceptable emission levels which can be translated into realistic abatement programs as required to alleviate both chronic and acute environmental damage. This may necessitate issuance of a revised Control Order.

## FINDINGS

As a result of this survey of the Smelter, Iron Ore Recovery Plant and Nickel Refinery owned and operated by Inco Limited in the Regional Municipality of Sudbury, the following findings are ascribed:

1. The emissions of sulphur dioxide from the Smelter 1250' chimney has and will on occasion result in concentrations of sulphur dioxide, at a point of impingement, in excess of the standards set out in Regulation 15 under The Environmental Protection Act, 1971.
2. Based on the estimated emissions of sulphur dioxide and nickel emitted from the Iron Ore Recovery Plant 637' chimney, calculated ground level concentrations of sulphur dioxide and total nickel on occasion will exceed the standards set out in Regulation 15 under The Environmental Protection Act, 1971.

## CONCLUSIONS

As a result of this survey, it is concluded that:

1. The operations of the Iron Ore Recovery Plant give rise to liquid effluents which are discharged along with other process wastes and natural drainage via Copper Cliff Creek and: (1) contain a nitrogenous oxygen demand which impairs the quality of the receiving waters, (2) contains nitrogen compounds in amounts which contribute to a nutrient problem and, (3) contribute to toxic conditions (to fish) in Copper Cliff Creek.
2. Qualitative data relating to emissions of particulate and sulphur dioxide, that result from the operation of the smelter and are emitted via low level natural draft and forced draft vents, indicate that these emissions may result in ground level concentrations substantially in excess of standards in Regulation 15.
3. Ground level concentrations of particulate (elemental and total particulate) and acid as calculated based on procedures detailed in Regulation 15 and maximum emission values recorded since 1974 for the Smelter 1250' chimney emissions, comply with standards in Regulation 15. It is noted that the quantity of pollutants emitted from test to test, varies considerably and does not allow a firm assessment of daily variability.

4. Qualitative data available, relating to emissions of particulate from the sinter machine exhaust stacks at the Iron Ore Recovery Plant, is insufficient to allow an assessment of whether these emissions comply with Regulation 15.
5. Qualitative data available, related to ammonia emissions from the Iron Ore Recovery Plant, indicate that these emissions may result in ground level concentrations of ammonia in excess of standards in Regulation 15, however, insufficient data is available to draw a firm conclusion.
6. Insufficient data is available to permit an assessment of whether low level emissions from the Nickel Refinery complex comply with standards in Regulation 15, for ground level nickel concentrations.
7. Environmental concerns being addressed under the auspices of the Sudbury Environmental Study, may necessitate more stringent abatement programs related to the control of sulphur dioxide, particulate and sulphuric acid emissions in the Sudbury basin.

## FEASIBILITY OF CONTROL

Sulphur dioxide and nickel emission problems, relating to emissions from the Iron Ore Recovery Plant 637' chimney, have been identified. This sulphur dioxide emission may be controlled to comply with standards in Regulation 15, through judicious sequencing of converter operation in the Nickel Refinery related to overall emission level and dispersion conditions, in conjunction with close control and response to butterfly damper trips in the fluid bed roaster gas handling system at the Iron Ore Recovery Plant and, maintenance of high conversion efficiency in the CIL Acid Plants. It is recognized that such sequencing of operations will result in fluctuations in production levels and hence be difficult to manage under the additional existing constraint of a daily mass balance. Nickel emissions from the 637' chimney may be reduced through provision of additional particulate removal capability either via improved efficiency in the existing electrostatic precipitators or through additional electrostatic precipitator capacity.

High ground level concentrations of sulphur dioxide have been noted, related to process gases emitted via the Smelter 1250' chimney. Conditions when high concentrations at ground level can be expected are generally related to minimal cloud cover, high solar angle and low wind speed. The frequency, duration and magnitude of these high ground level concentrations of sulphur dioxide, can only be reduced through reduction of emissions either via provision of sulphur dioxide fixation facilities i.e. acid plants, etc., or via reduced production levels and hence emission levels. To date, control has been achieved by a combination of these techniques i.e. reduction of SO<sub>2</sub> emissions on a continuous

basis through production of liquid  $\text{SO}_2$  and through rejection of pyrrhotite from the Smelter feed, and through reduction of sulphur dioxide emissions on a short term basis (relating to local meteorological conditions) through reduction of actual production. Short term control has been achieved using an emission reduction program which includes a meteorological data collection/interpretation/forecast module, an emission data collection module, a ground level sulphur dioxide monitoring/data feedback module and a data handling/modelling module. There are a number of means for temporary curtailment of sulphur dioxide emissions from the Smelter and under severe conditions, within 3 1/2 hours from the start of curtailment operations, emissions can be reduced to a level of about 800 tons per day. The flexibility and level of curtailment possible for short time intervals makes it possible and feasible to control ground level concentrations under all meteorological conditions to less than 0.5 ppm. Actual control achievement will be directly related to the reliability and accuracy of each module within the control system.

Data related to the actual performance of the Inco Limited system during 1976 and 1977 are presented in Table XIX and indicates that 86% of the controlled days required were actually predicted during the time interval, and further indicates that controls were sufficient for 80% of the predicted control days. It is anticipated that improvements in prediction/control performance can be expected with time, especially relating to adequacy of control once the prediction is made, and misses in performance should only be tolerated in relation to system capability i.e. prediction capability.

## RECOMMENDATIONS

It is recommended that Inco Limited be issued a control order under Section 6 of The Environmental Protection Act, a Requirement and Direction under Section 69 of The Ontario Water Resources Act and a Provincial Officer Requirement under Section 84 of The Environmental Protection Act, as follows:

### Control Order

1. Take such steps as are necessary so that emissions of sulphur dioxide into the natural environment:
  - (i) from the Copper Cliff Smelter when averaged over a calendar year shall not exceed 3,600 short tons per day;
  - (ii) from the Copper Cliff Smelter 1,250' chimney, either alone or in combination with other Inco Limited Sudbury emissions do not result in a measured hourly average groundlevel concentration in excess of 0.5 ppm and do not result in a measured 24 hour average groundlevel concentration in excess of 0.15 ppm.
2. (a) Have in place and operate a comprehensive system for a groundlevel sulphur dioxide concentration control system for the Copper Cliff Smelter designed to achieve compliance with paragraph 1 (a) (ii). The system shall include a prediction, control and



data handling capability and shall include at least the items noted in Appendix 1 which shall be in operation on or before the dates there set out.

- (b) (i) provide immediately to the Director a true copy of an operations manual describing the procedures for operation of the system required in Paragraph 2 (a) and provide to the Director forthwith any amendments to the manual.
- (ii) provide the Director or his staff with a plan each day prior to 8:30 a.m. for implementation of the system for the next 24 hours and provide forthwith any amendments to the plan.
- (iii) file with the Director or his staff within 32 hours of the end of the period a log recording the operation of the system for the 24 hour period referred to in the paragraph above.
- (iv) file with the Director within 60 days of the end of each calendar year a summary of aggregate emissions from the Copper Cliff Smelter for such calendar year with supporting data sufficient to enable verification of the emissions.

- 3. (a) Take such steps as are necessary so that emissions of sulphur dioxide, into the natural environment, from the Iron Ore Recovery Plant complex, in the aggregate,

- (i) when averaged over a calendar year shall not exceed 250 short tons per day;
    - (ii) do not result in a measured or calculated hourly average groundlevel concentration in excess of 0.25 ppm.
  - (b) file with the Director within 60 days of the end of each calendar year a summary of aggregate emissions from the Iron Ore Recovery Plant for such calendar year with supporting data sufficient to enable verification of the emissions.
4. (a) On or before July 31, 1979, complete the installation, construction or arrangement and have in operation electrostatic precipitators treating gases emitted from the Nickel Refinery TBR converters via the flue system to the Iron Ore Recovery Plant designed such that emissions of nickel in free and combined form from the 637' Iron Ore Recovery Plant chimney at a point of impingement do not exceed the standards set out in Regulation 15 under The Environmental Protection Act, 1971.
- (b) On or before December 31, 1979, submit an evaluation report on the effectiveness of the electrostatic precipitators noted in 4 (a) accompanied by an outline of any further action and/or facilities that may be needed to provide compliance with Regulation 15 under The Environmental Protection Act, 1971.

### Requirement & Direction

1. By December 31, 1979 conduct an investigation and report thereon, in writing, to the Director evaluating means of achieving reductions of nitrogen loadings in Copper Cliff Creek in a staged program so as to achieve a cumulative reduction of 90 per cent of the total nitrogen loading in Copper Cliff Creek.

### Provincial Officer Requirement

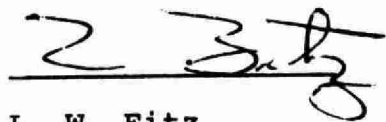
1. Carry out an investigation and report in writing by December 31, 1979 evaluating the feasibility of controlling sulphur dioxide emissions from the Copper Cliff Smelter 1,250' chimney as required to achieve a maximum hourly average groundlevel concentration of not greater than 0.25 ppm.
2. Conduct emission tests at the Copper Cliff Smelter as required to quantify the amount of sulphur dioxide and particulate (including sufficient elemental analysis to characterize the composition) that result from operations of the converters and reverberatory furnaces and are emitted at low level via forced draft and natural draft vents and submit a report, in writing, on the above by December 31, 1979.
3. Conduct emission tests at the Copper Cliff Smelter as required to quantify the amount of sulphur dioxide and particulate (including sufficient elemental analysis to characterize the composition) that result from the

operations of the roasters and copper flash furnace and are emitted at low level and submit a report, in writing, on the above by December 31, 1980.

4. Carry out an investigation and submit a report, in writing, by December 31, 1981 evaluating the feasibility of controlling low level emissions from the Copper Cliff Smelter noted in items 2 and 3 as required to achieve compliance with Regulation 15 under The Environmental Protection Act, 1971.
5. Conduct at least 16 emission tests and report, in writing, by December 31, 1979 the quantity of sulphuric acid and particulate (including sufficient elemental analysis to characterize the composition) emitted from the 1,250' chimney with the quantification based on a testing frequency of not less than once per month with supporting information as required to assess daily variability during the reporting period.
6. Conduct emission tests and submit a report, in writing, by December 31, 1979 evaluating the significance, nature and quantity of particulate and ferric oxide emissions from the sinter machine exhaust stacks at the Iron Ore Recovery Pellet Plant.
7. Conduct tests and report, in writing, by December 31, 1979, evaluating ammonia levels measured at points of impingement at the perimeter of the iron ore recovery plant property.

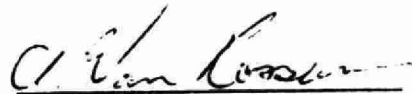
8. Investigate and submit a report in writing by December 31, 1979 evaluating the significance and quantity of low level emissions of nickel from the Copper Cliff Nickel Refinery.

Prepared by:



L. W. Fitz  
Provincial Officer

and

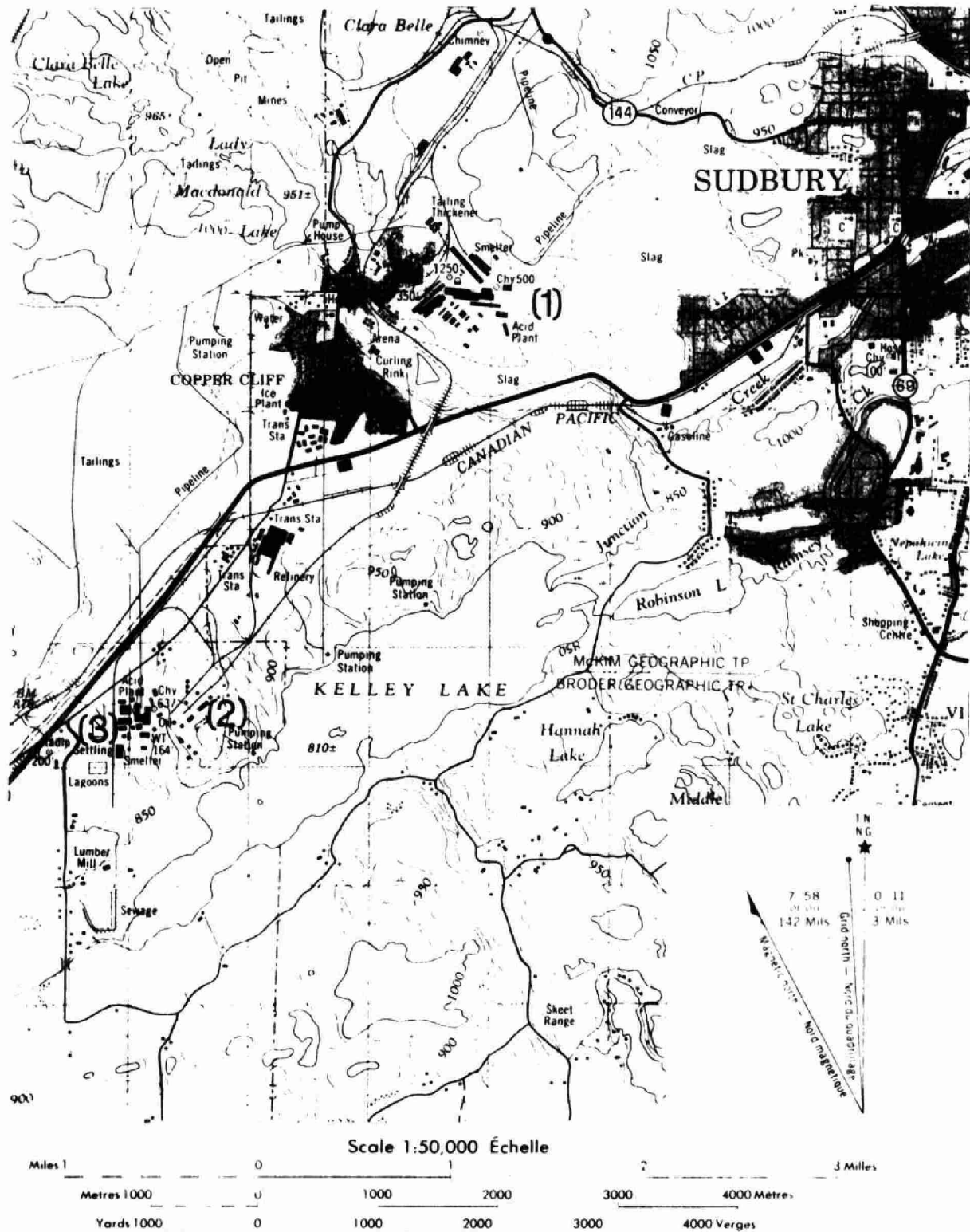


A. Van Rossum  
Provincial Officer

Figure 1

PLANT LOCATIONS INCO LIMITED

- 1 Smelter
- 2 Nickel Refinery
- 3 Iron Ore Recovery Plant



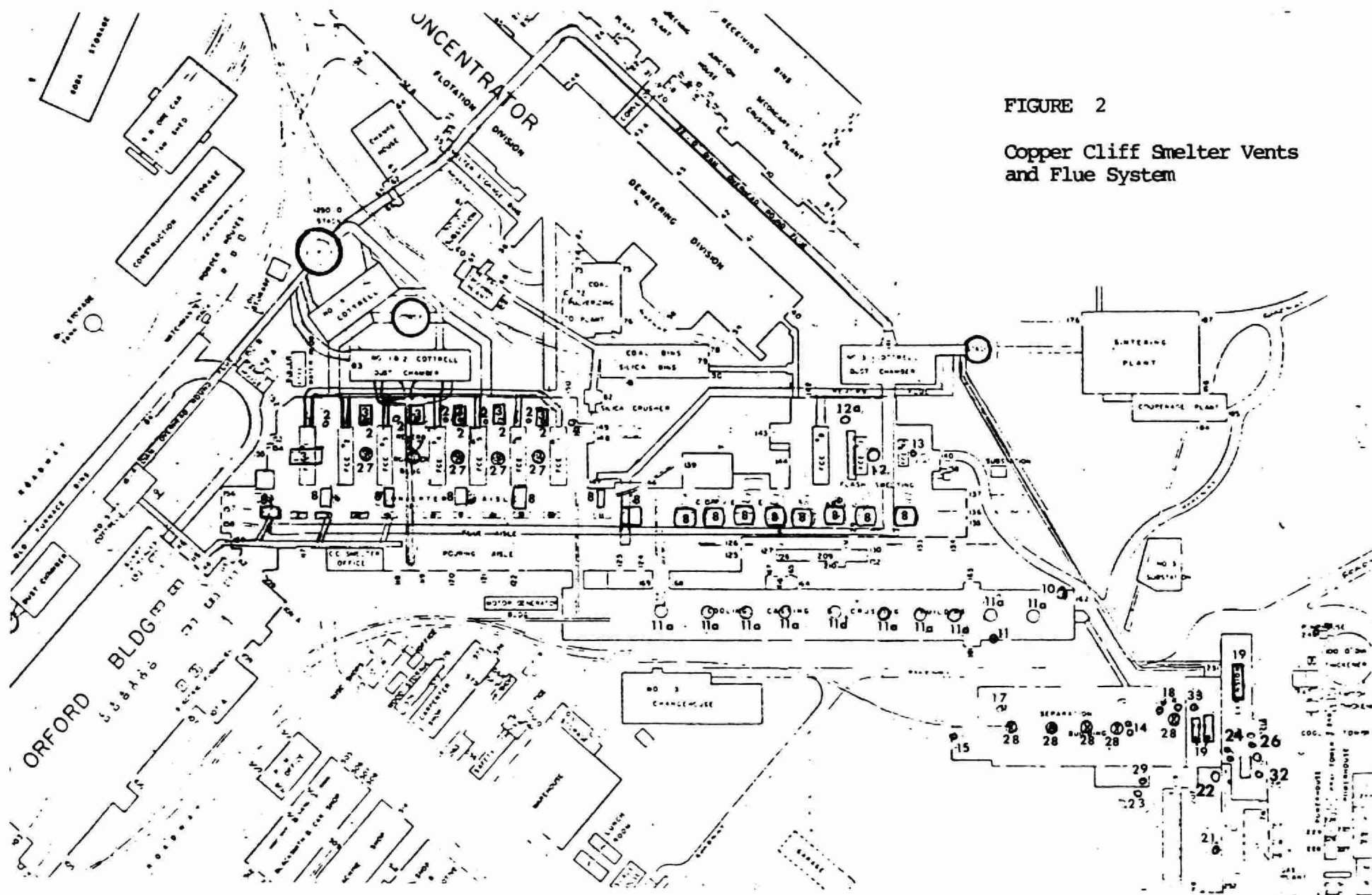
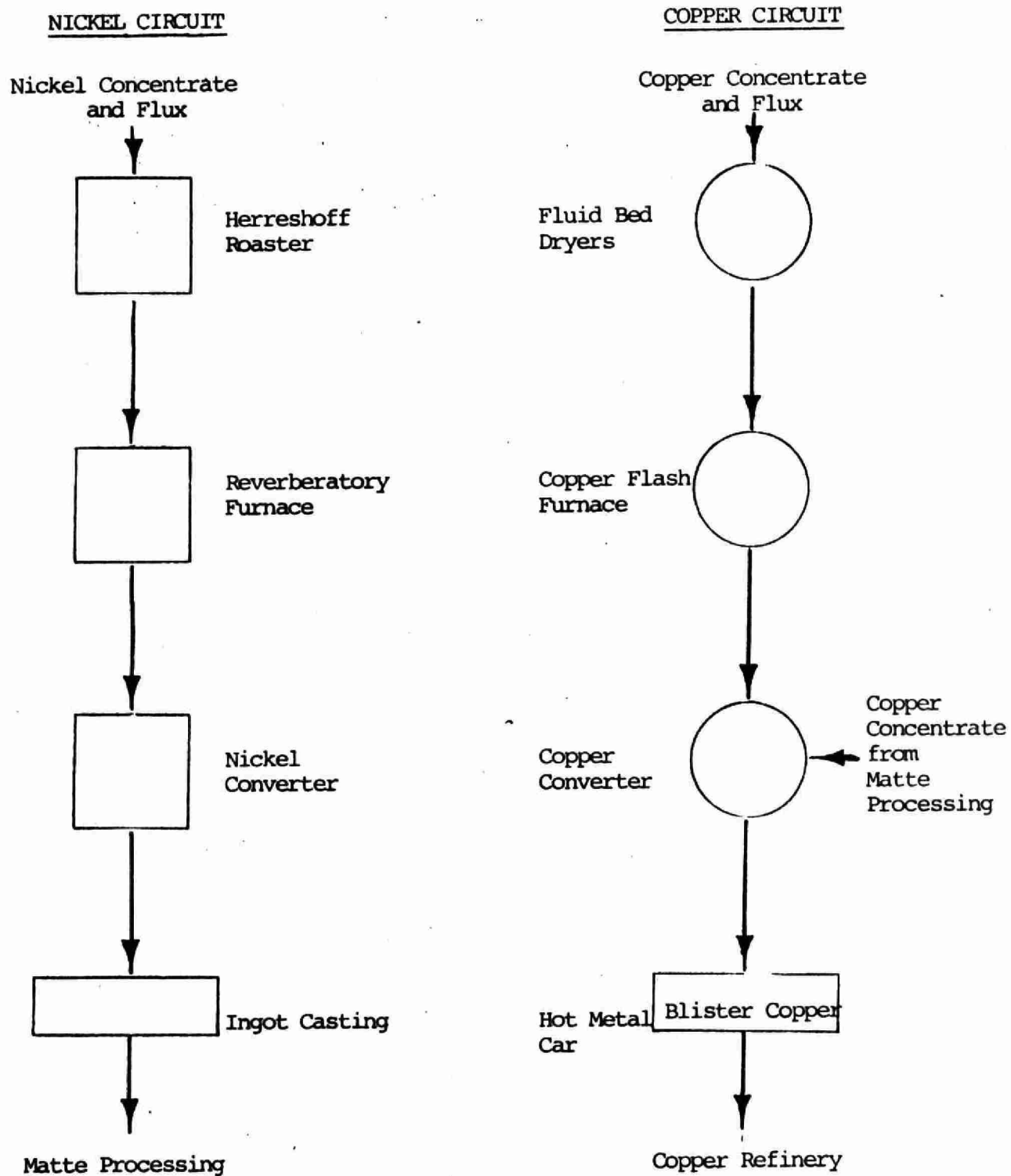


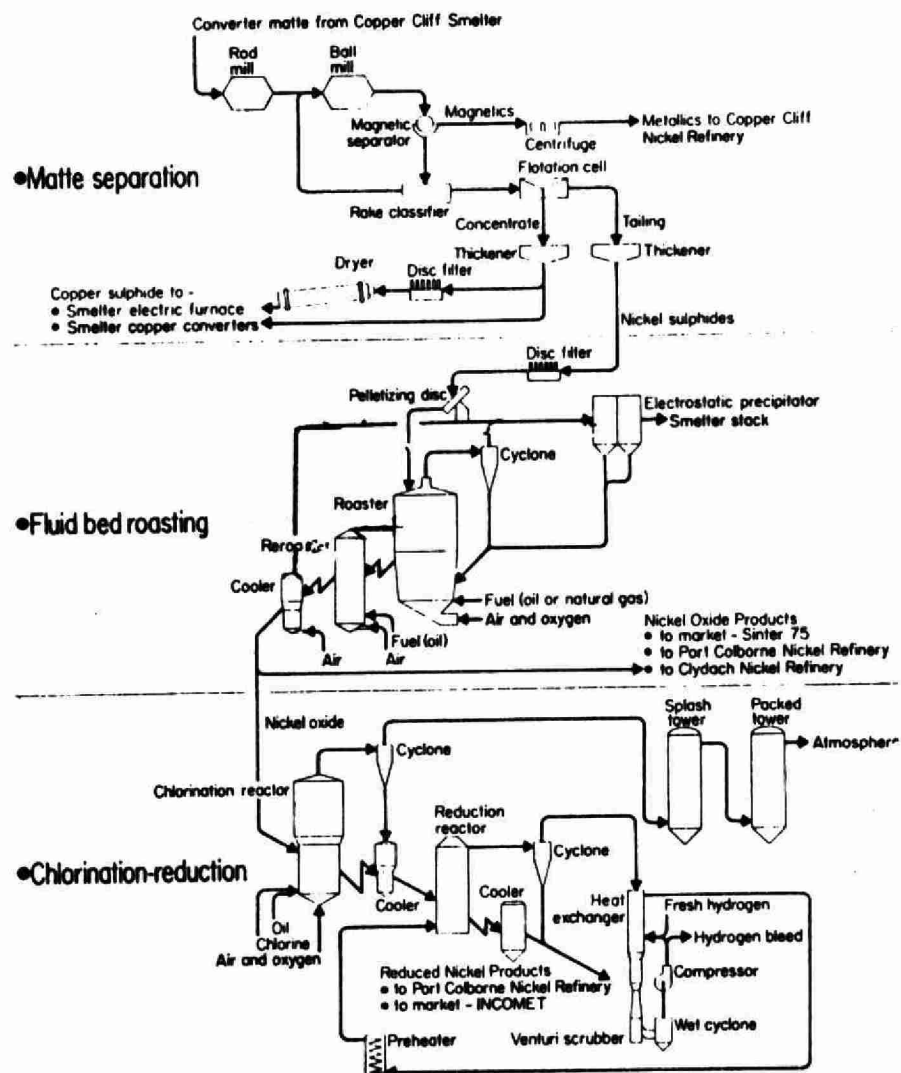
FIGURE 3

Smelter Block Process Flowsheet





INCO LTD. Smelter - Matte Processing Flowsheet



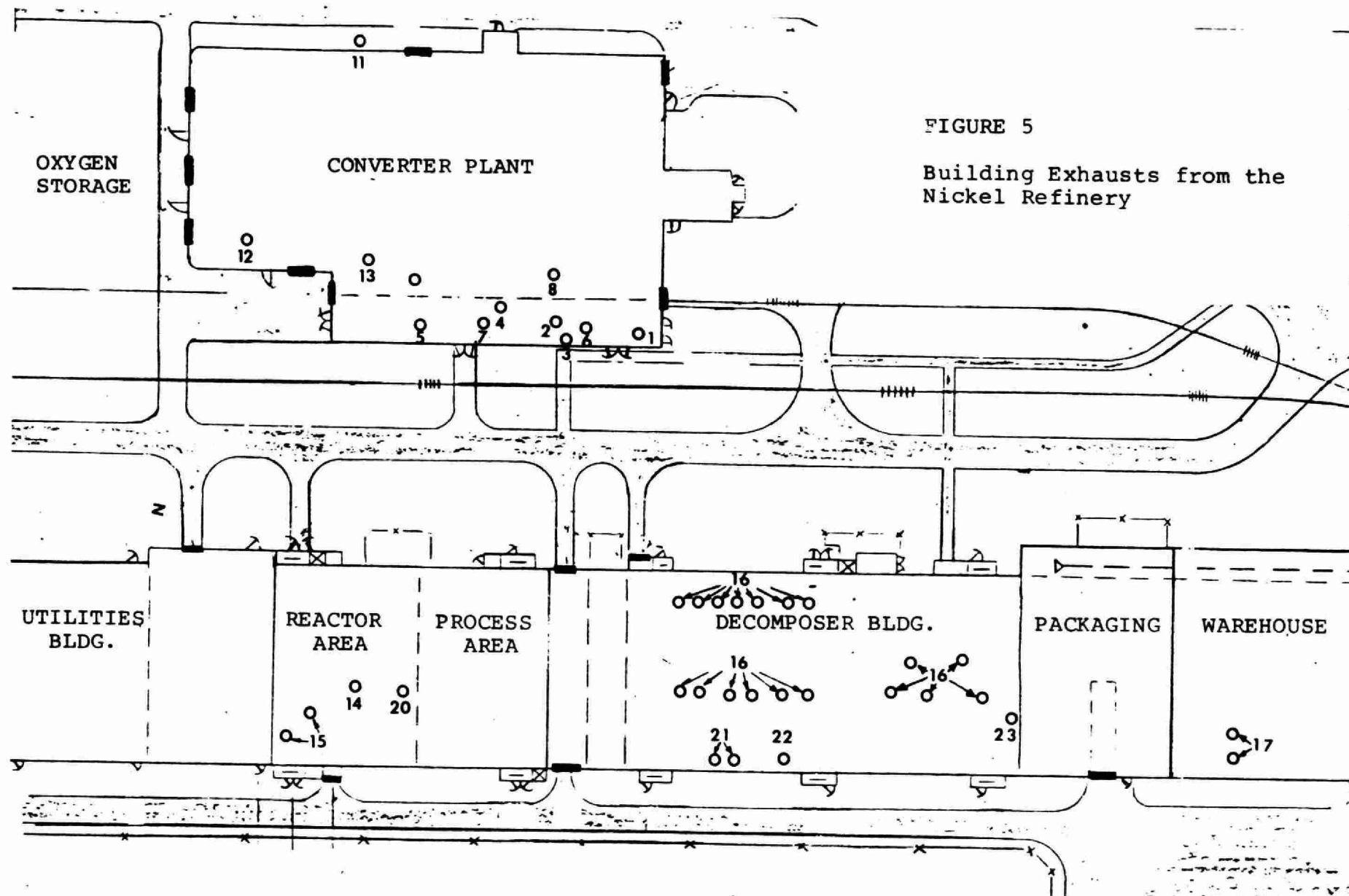


FIGURE 5

Building Exhausts from the  
Nickel Refinery

FIGURE 6

INCO Ltd. Nickel Refinery Process Flowsheet

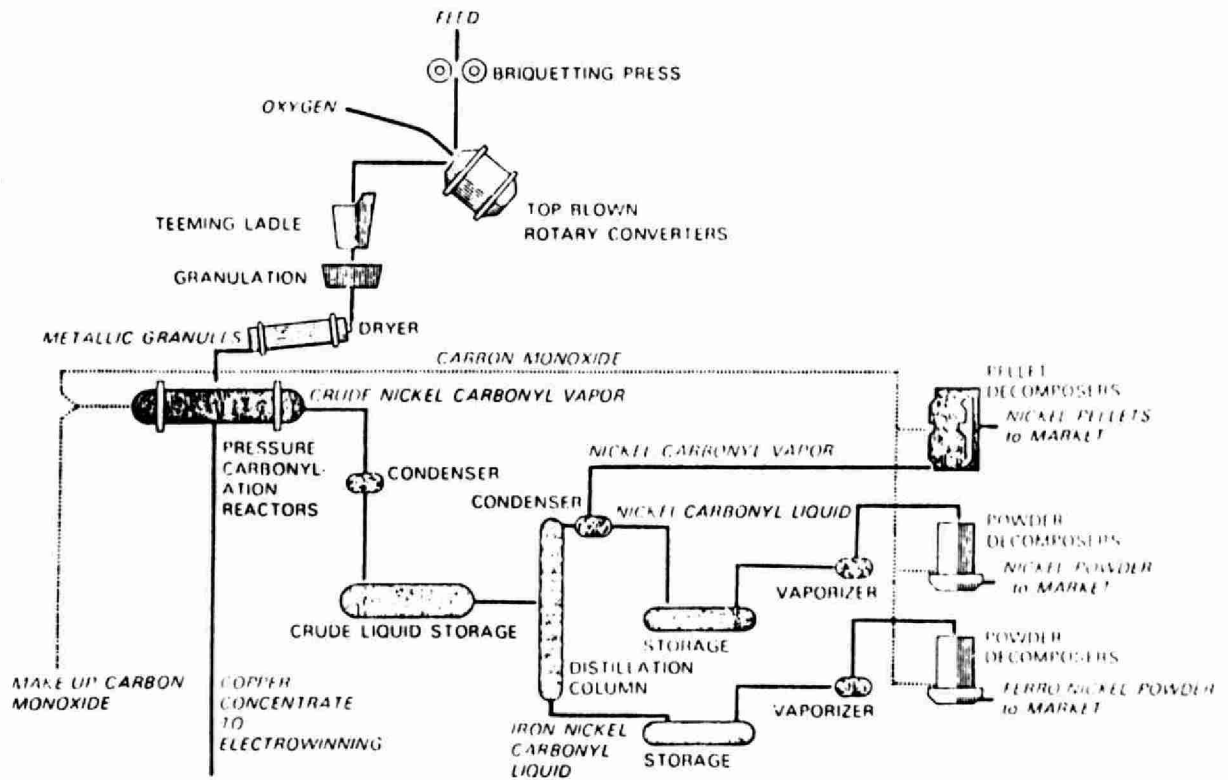
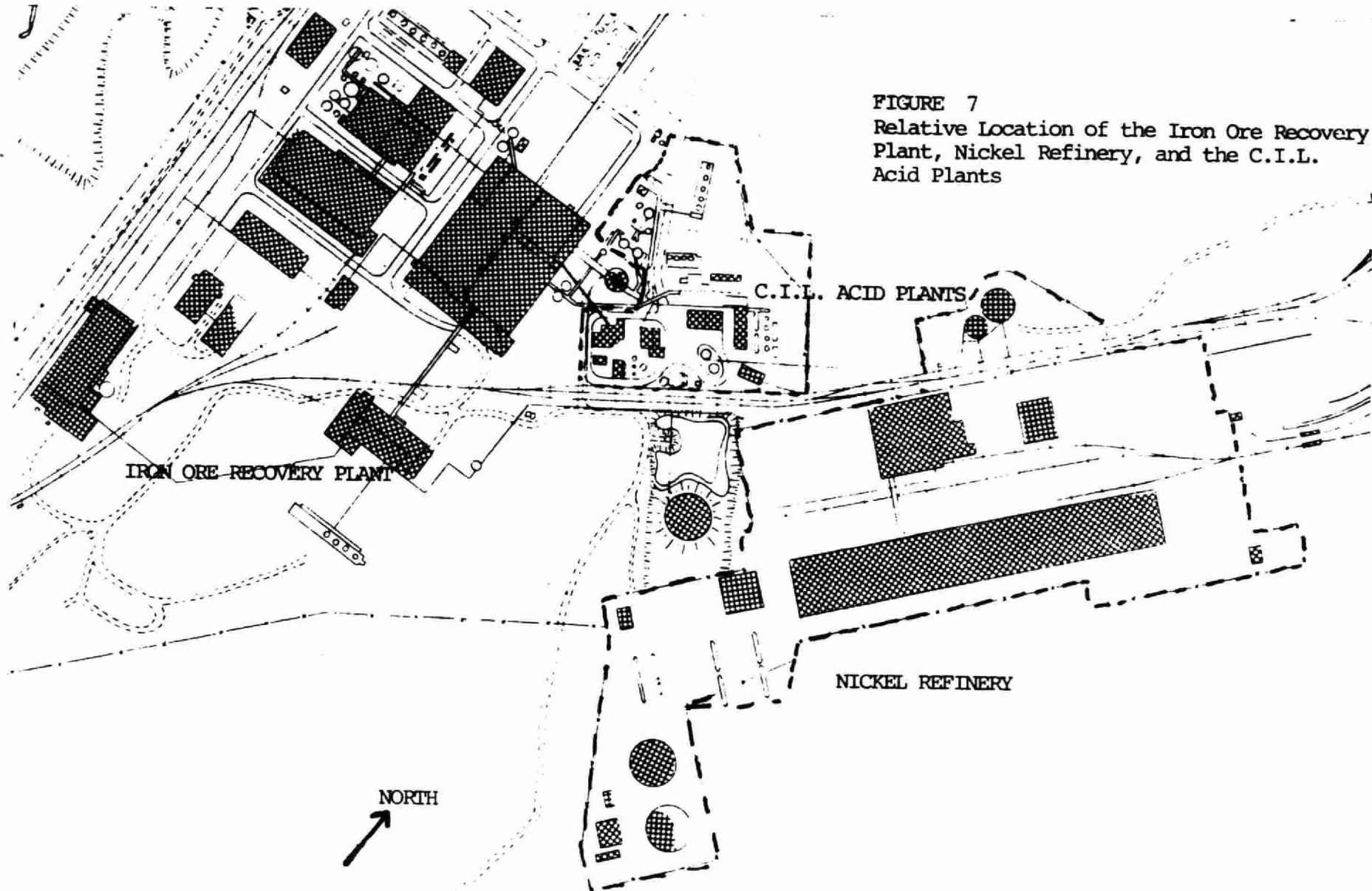
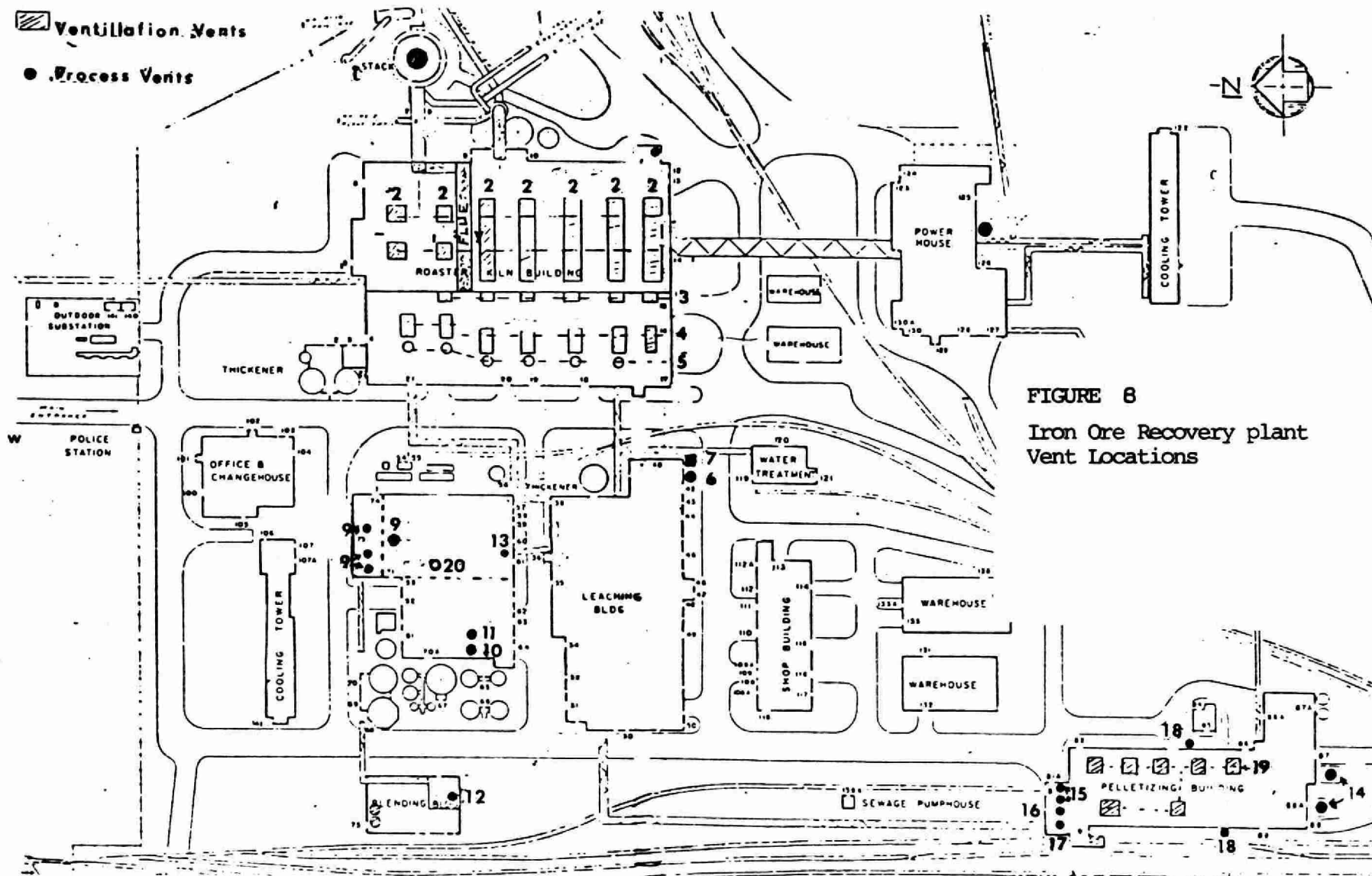
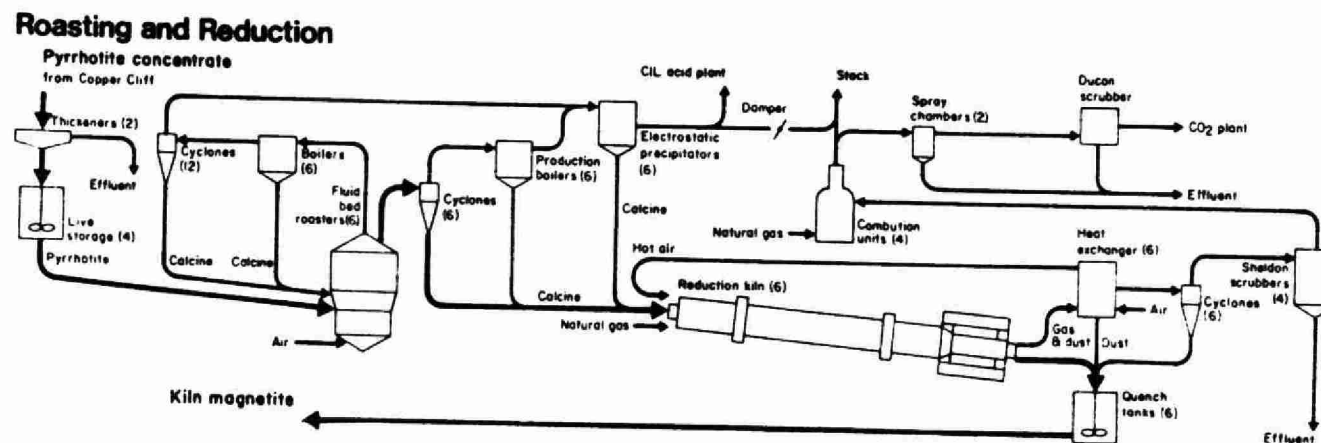


FIGURE 7  
Relative Location of the Iron Ore Recovery  
Plant, Nickel Refinery, and the C.I.L.  
Acid Plants





INCO Ltd. Iron Ore Recovery Plant  
Roasting System



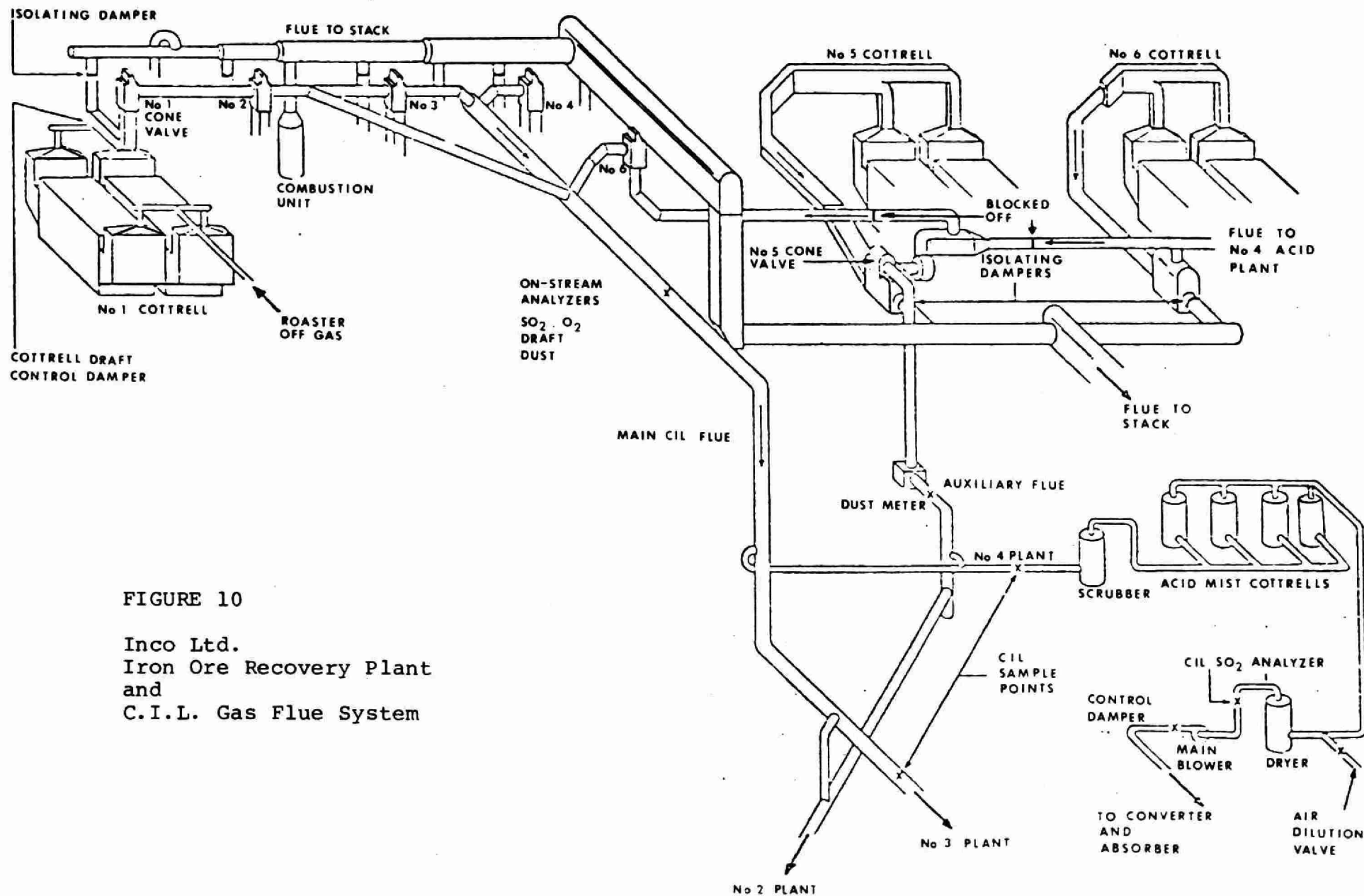
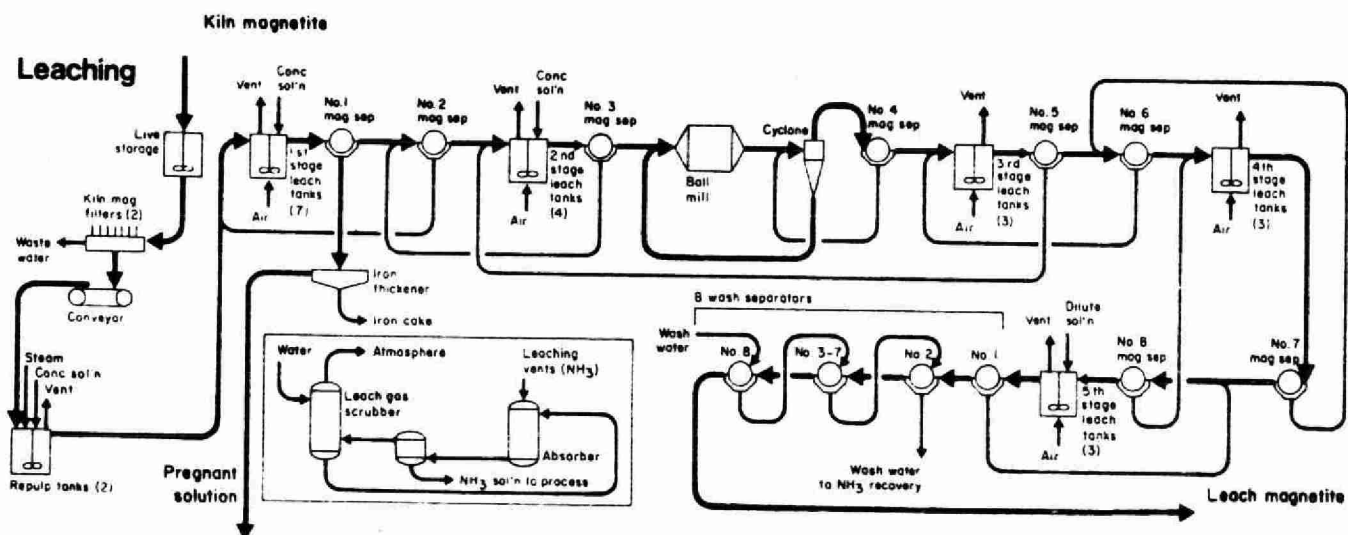


FIGURE 10

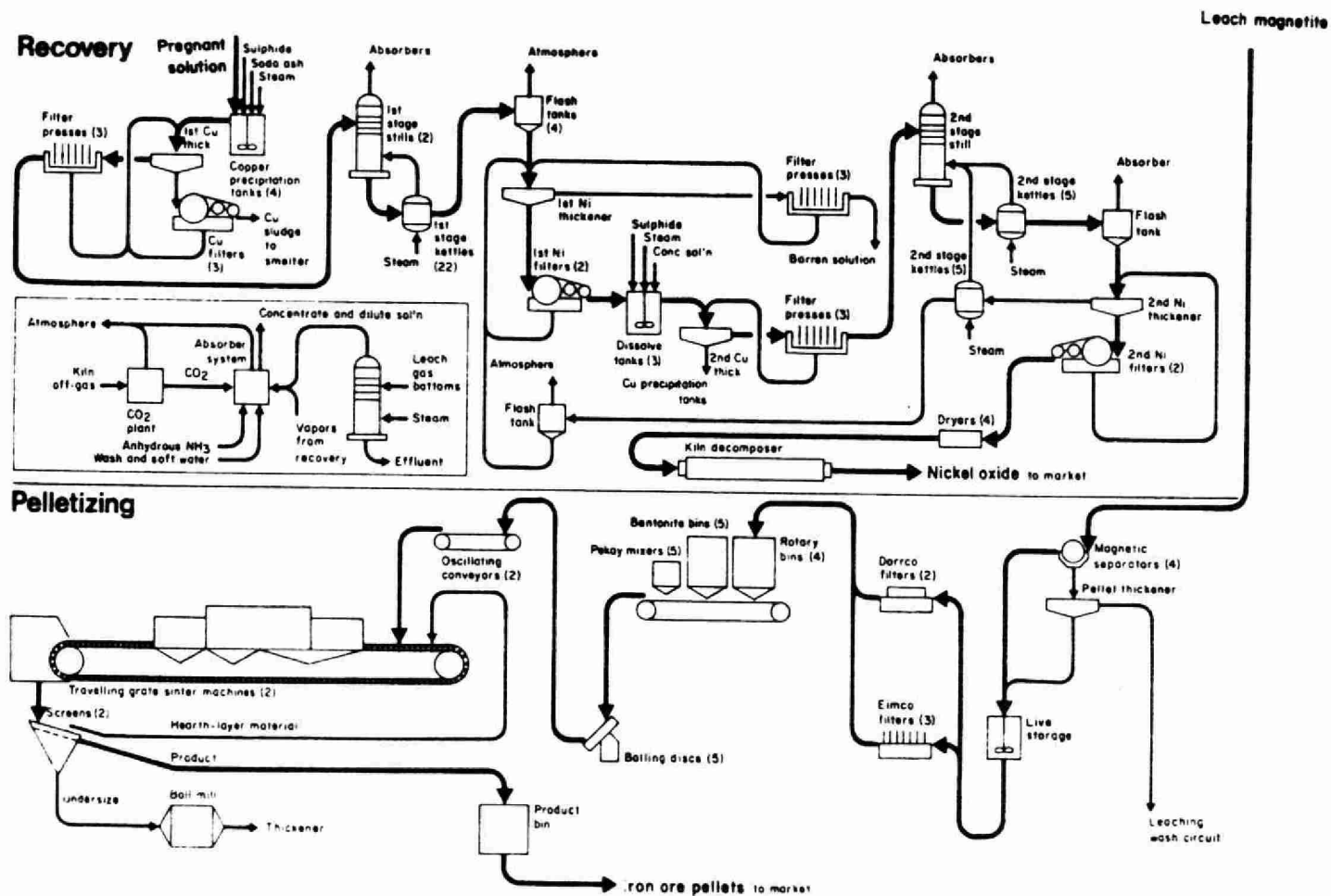
Inco Ltd.  
Iron Ore Recovery Plant  
and  
C.I.L. Gas Flue System

FIGURE 11





INCO Ltd. Iron Ore Recovery Plant  
Recovery and Pelletizing Systems



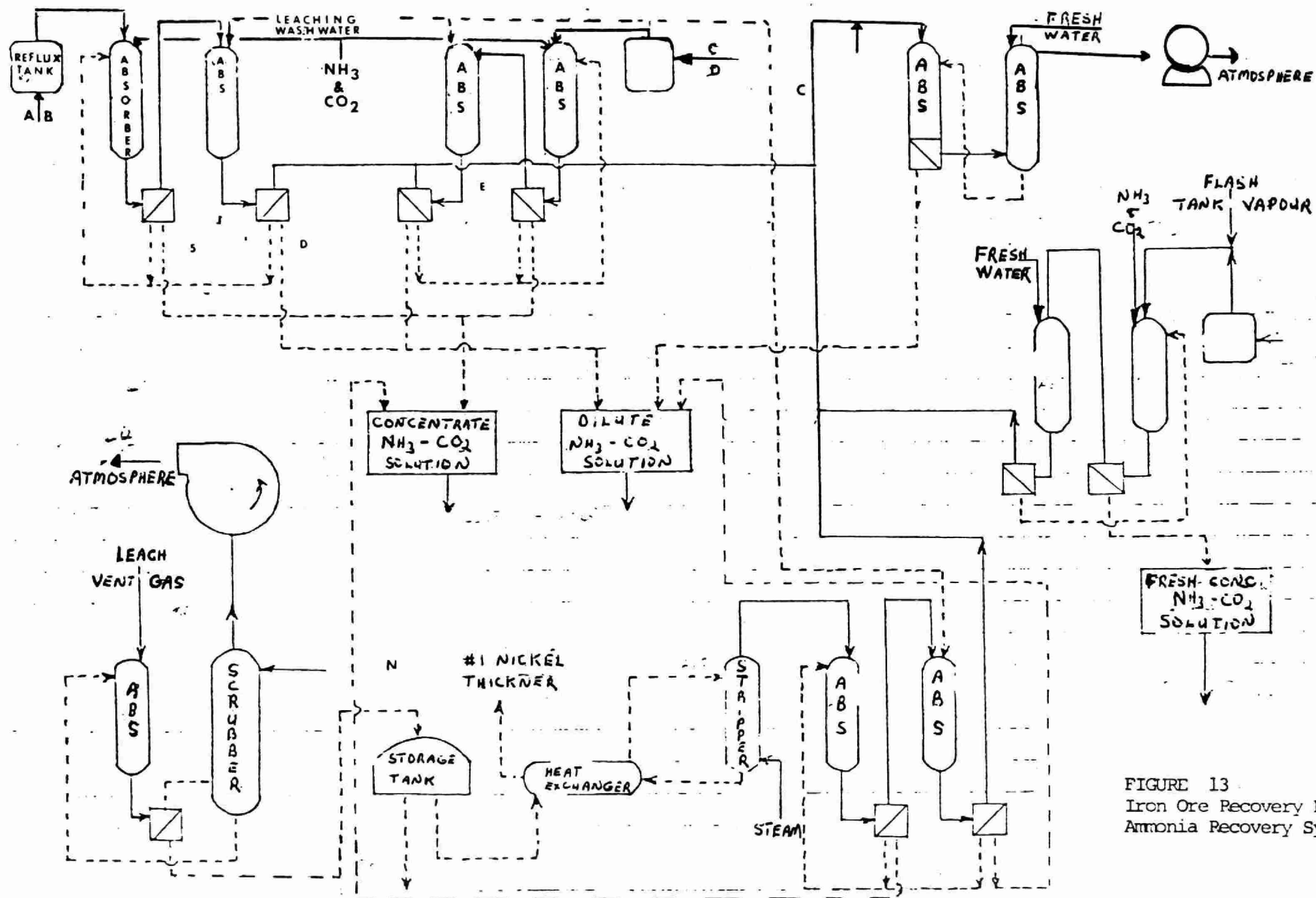


FIGURE 13  
Iron Ore Recovery Plant  
Ammonia Recovery System

FIGURE 14

EMISSION SOURCES GLC's

Low Level (150 T/D) \_\_\_\_\_

1250' Chimney (3600 T/D) - - - -

I.O.R.P. Chimney (250 T/D) . . . . .

C-Stability

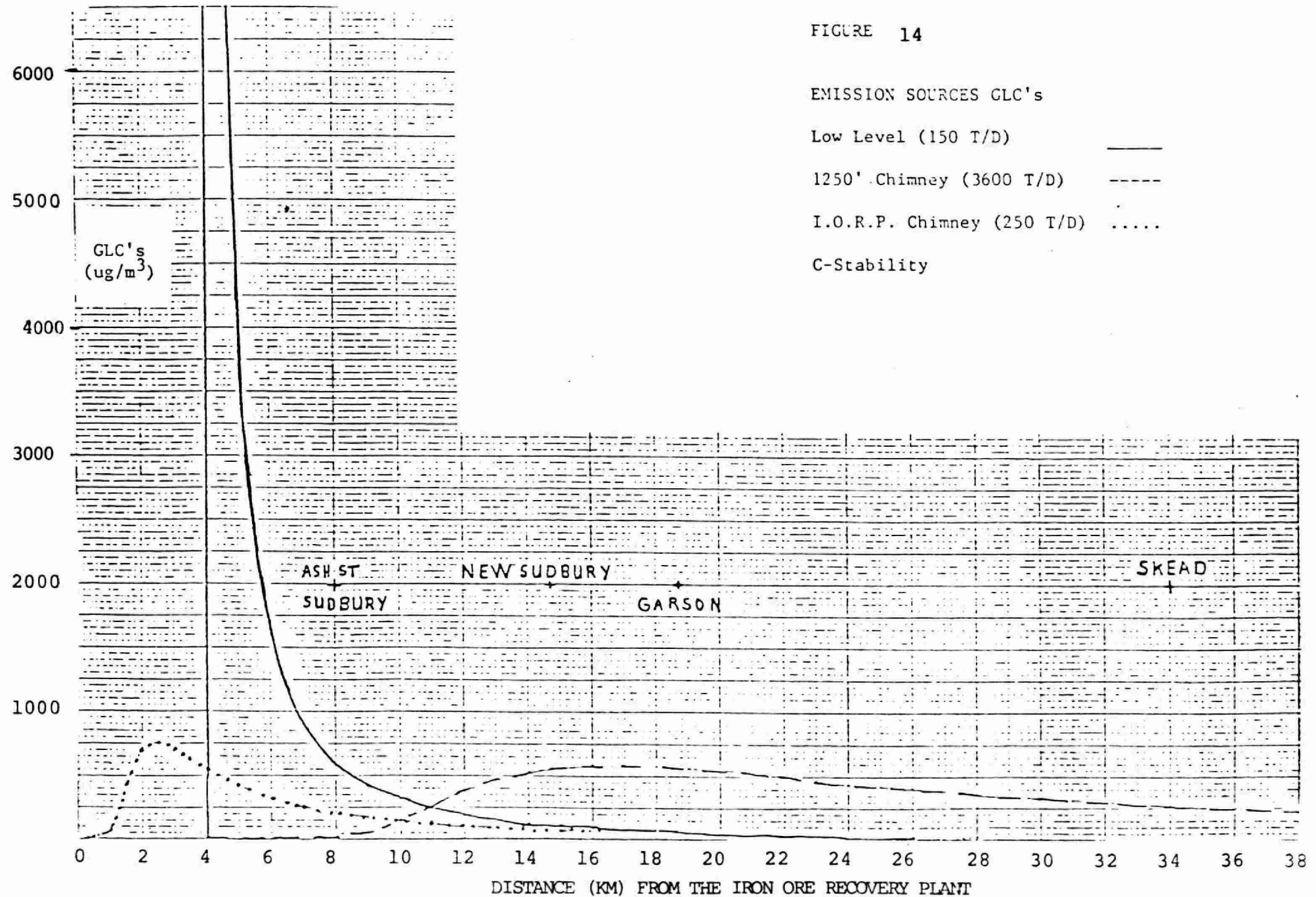


FIGURE 15

Continuous SO<sub>2</sub> Monitoring Sites

LEGEND:

- - Continuous SO<sub>2</sub> Monitor
- ⊙ - Air Pollution Index Station

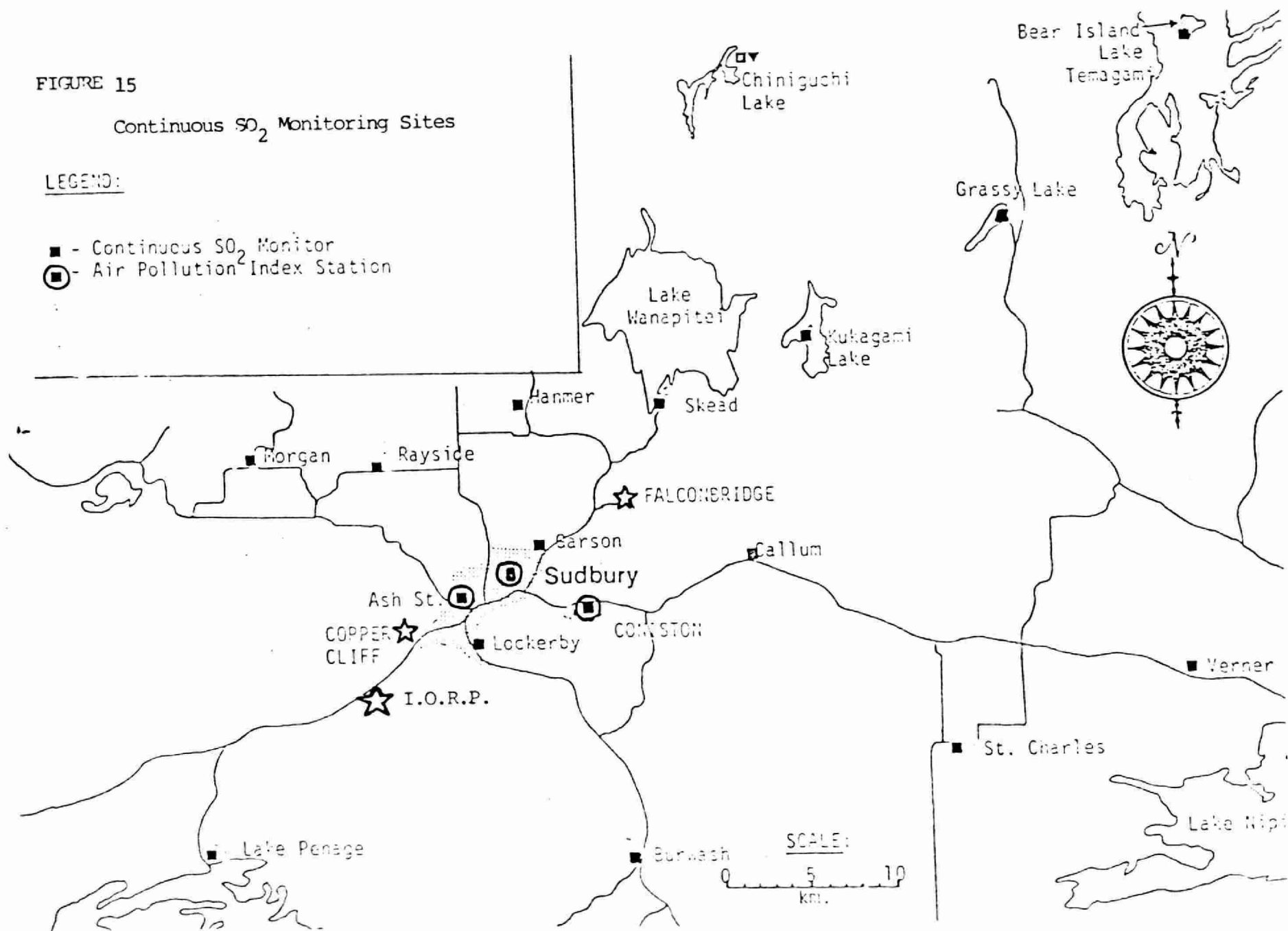


TABLE I  
INCO LIMITED  
Copper Cliff Smelter Emissions

| <u>EMISSION NO.</u> | <u>SOURCE</u>                                                          | <u>CONTROL DEVICE</u> | <u>EXHAUST ELEVATION</u> |
|---------------------|------------------------------------------------------------------------|-----------------------|--------------------------|
| 1                   | Roasters                                                               | ESP #1                | 1250'                    |
| 2                   | Reverberatory pouring hood exhausts                                    |                       | 153'                     |
| 3                   | Reverberatory Monitors                                                 |                       | 153'                     |
| 4                   | Reverberatory furnaces                                                 | ESP #4                | 1250'                    |
| 5                   | Converters #1,3,5                                                      | ESP #5                | 1250'                    |
| 6                   | Converters #2 - 10                                                     | ESP #2                | 1250'                    |
| 7                   | Converters #11 - 19                                                    | ESP #3                | 1250'                    |
| 8                   | Converter Monitors                                                     |                       | 153'                     |
| 9                   | Copper Oxygen Flash Furnace<br>(Diverted gas or gas returned from CIL) | ESP #3                | 1250'                    |
| 10                  | Casting Building Crusher & Conveyors                                   | Baghouse              | 9'                       |
| 11                  | Casting Building Crusher Conveyors                                     | Baghouse              | 14'                      |
| 11(a)               | Casting Building Roof Vents (10)                                       |                       | 153'                     |
| 12                  | Flash Furnace vent stack (8' diameter)                                 |                       |                          |
| 12(a)               | Flash furnace pouring hood exhaust                                     |                       | 153'                     |
| 13                  | SO <sub>2</sub> Scrubber vent stack                                    |                       |                          |
| 14                  | A & B Circuit Nickel Matte Bin & Conveyors                             | Baghouse              | 101'                     |
| 15                  | C circuit bin and conveyors                                            | Baghouse              | 101'                     |
| 16                  | A & B Primary Ball Mill vent                                           | Scrubber              | 114'                     |
| 17                  | Copper Concentrate dryer                                               | Cyclone & Scrubber    | 114'                     |
| 18                  | Fluid bed roaster pelletizing discs (2)                                | Baghouse              | 133'                     |
| 19                  | Fluid bed roaster roof monitors (4)                                    |                       | 133'                     |
| 20                  | Fluid Bed Roasters                                                     | ESP                   | 1250'                    |

TABLE I (CONTINUED)

| <u>EMISSION<br/>NO.</u> | <u>SOURCE</u>                                      | <u>CONTROL DEVICE</u>                       | <u>EXHAUST<br/>ELEVATION</u> |
|-------------------------|----------------------------------------------------|---------------------------------------------|------------------------------|
| 21                      | Packaging                                          | Baghouse                                    | 66'                          |
| 22                      | Conveyors & Dust Bins                              | Baghouse                                    | 133'                         |
| 23                      | Bulk Unloading                                     | Baghouse                                    | 49'                          |
| 24                      | Chlorination Reactor                               | Splash tower<br>Packed tower<br>and Wet ESP |                              |
| 25                      | Cooler vent                                        | Scrubber                                    |                              |
| 26                      | Chlorination product reactor bins<br>and conveyors | Scrubber                                    |                              |
| 27                      | Roaster fans                                       |                                             | 153'                         |
| 28                      | Separation building roof fans                      |                                             | 133'                         |
| 29                      | Lime storage bin                                   | Baghouse                                    |                              |
| 30                      | Bleed off Hydrogen                                 | Flare                                       | 133'                         |
| 31                      | Preheater Stack                                    |                                             | 133'                         |
| 32                      | Balling disc and conveyors                         | Baghouse                                    | 133'                         |

## NOTE:

ESP = electrostatic precipitator

TABLE II

## INCO LIMITED

## Nickel Refinery Emissions

| <u>EMISSION<br/>NO.</u> | <u>SOURCE</u>                          | <u>CONTROL<br/>DEVICE</u>               | <u>EXHAUST<br/>ELEVATION</u> |
|-------------------------|----------------------------------------|-----------------------------------------|------------------------------|
| 1                       | Primary metallic unloading             | Baghouse                                | 93'                          |
| 2                       | Coke unloading                         | Baghouse                                | 93'                          |
| 3                       | Raw material area                      | Baghouse                                | 93'                          |
| 4                       | Pug mill area                          | Baghouse                                | 93'                          |
| 5                       | Briquette storage                      | Baghouse                                | 93'                          |
| 6                       | Coke hoppers                           | Baghouse                                | 93'                          |
| 7                       | Charge hoppers                         | Baghouse                                | 93'                          |
| 8                       | Carging elevators                      | Baghouse                                | 93'                          |
| 9                       | Converter Hoods (2)                    | Electrostatic<br>Precipitator           | 637'                         |
| 10                      | Converter roof vents                   |                                         | 108'                         |
| 11                      | Ladle preheat exhaust                  | Scrubber                                |                              |
| 12                      | Granulation vent                       |                                         | 117'                         |
| 13                      | Rotary drier                           | Scrubber                                | 117'                         |
| 14                      | storage hopper                         | Baghouse                                | 168'                         |
| 15                      | Dust hood for charging reactors        | Baghouse                                | 168'                         |
| 16                      | Decomposer preheater exhausts (18)     |                                         | 13 @ 92'<br>5 @ 112'         |
| 17                      | Packaging department vents (2)         | Baghouse                                | 63'                          |
| 18                      | Nickel-Powder decomposers              | Baghouse and recycle<br>or flare system | 150'                         |
| 19                      | Iron Nickel power decomposers          | Baghouse and recycle<br>or flare system | 150'                         |
| 20                      | Mea stripper                           |                                         | 150'                         |
| 21                      | Vacuum cleaning (2) decomposer<br>area | Baghouse                                | 150'                         |
| 22                      | Decomposer area packaging              | Baghouse                                | 150'                         |

TABLE III

## INCO LIMITED

## Iron Ore Recovery Plant Emissions

| <u>EMISSION<br/>NO.</u> | <u>SOURCE</u>                               | <u>CONTROL<br/>DEVICE</u>                             | <u>EXHAUST<br/>ELEVATION</u> |
|-------------------------|---------------------------------------------|-------------------------------------------------------|------------------------------|
| 1                       | Roasters                                    | Electrostatic<br>Precipitator & C.I.L.<br>acid plants | 637'                         |
| 2                       | Roaster ventilators (7)                     |                                                       | 95'                          |
| 3                       | Kiln monitors (6)                           |                                                       | 50'                          |
| 4                       | Kiln cooler vents (7)                       |                                                       | 50'                          |
| 5                       | Kiln discharge ventilation fan (6)          |                                                       | 60'                          |
| 6                       | Leaching tank vents                         | Scrubber & Absorber<br>Scrubber                       | 60'                          |
| 7                       | Steam drier of Cu-Ni sulphide               | Scrubber                                              | 60'                          |
| 8                       | Leaching building roof fan<br>exhausts (25) |                                                       | 60'                          |
| 9                       | Belt filters (4)                            |                                                       | 60'                          |
| 10                      | Steam drier                                 | Scrubber                                              | 60'                          |
| 11                      | Kiln decomposer                             | Scrubber                                              | 60'                          |
| 12                      | Airslide conveyor and tank                  | Baghouse                                              | 73'                          |
| 13                      | Ammonia recovery                            | Absorbers                                             | 73'                          |
| 14                      | Sinter machine stacks (2)                   |                                                       | 150'                         |
| 15                      | Sinter machine drop off (2)                 | Scrubber                                              | 110'                         |
| 16                      | Screening exhausts                          | Scrubber                                              | 110'                         |
| 17                      | Loadout area                                | Scrubber                                              | 110'                         |
| 18                      | Sinter machine bleed off (2)                |                                                       | 110'                         |
| 19                      | Cooling vents (7)                           |                                                       | 110'                         |
| 20                      | CO <sub>2</sub> recovery exhaust            |                                                       | 73'                          |



TABLE IV

## INCO LIMITED

APPROXIMATE GAS AND SULPHUR DIOXIDE  
DISTRIBUTION FOR COPPER CLIFF SMELTER

| Smelting Unit                              | Gas Volume<br>Actual cfm | Temperature<br>°F | Volume<br>% SO <sub>2</sub> | Tons/Day<br>SO <sub>2</sub> |
|--------------------------------------------|--------------------------|-------------------|-----------------------------|-----------------------------|
| Herreshoff Roasters                        | 1,000,000                | 300               | 1.0                         | 920                         |
| Reverberatory<br>Furnaces                  | 1,600,000                | 600               | 0.5                         | 460                         |
| Nickel Converters                          | 1,500,00                 | 300               | 1.0                         | 1,260                       |
| Matte Processing<br>Fluid Bed Roasters     | 200,000                  | 500               | 3.0                         | 320                         |
| Copper Flash Furnace                       | 4,000                    | 1,500             | 80.0                        | 140 <sup>(1)</sup>          |
| Copper Converters                          | 600,000                  | 300               | 1.0                         | 500                         |
| Miscellaneous Process<br>Gas and Inleakage | 1,000,000                | 60                | 0.0                         | 0                           |
| TOTAL TO STACK                             | 6,000,000                | 300               | 0.7                         | 3,600                       |

NOTE:

- (1) Copper flash furnace SO<sub>2</sub> production averages about 440 TPD. Normally about 300 TPD is converted to liquid SO<sub>2</sub> for sale and, on average, 140 TPD is vented to the chimney system.
- (2) Reference: July 5, 1976 - Inco Program Submission

TABLE V

INCO LIMITED  
AVERAGE SO<sub>2</sub> EMISSIONS FROM THE  
COPPER CLIFF SMELTER (tons per day)

| <u>Date</u> | <u>Emission Level</u> |
|-------------|-----------------------|
| 1960        | 5496                  |
| 1970        | 4620                  |
| 71          | 4114                  |
| 72          | 3707                  |
| 73          | 3263                  |
| 74          | 3448                  |
| 75          | 3493                  |
| 76          | 3557                  |
| 77          | 3275                  |

NOTE:

- (1) Emission levels represent yearly total emissions divided by 365.
- (2) Emission levels are based on metallurgical mass balancing techniques and represent total emissions of S as SO<sub>2</sub> from the smelter.
- (3) Low level contribution is estimated qualitatively to be 4% of total emissions.
- (4) Reference:
  - i) 1977 Fourth Quarter Report - INCO
  - ii) July 5, 1976 - INCO Program Submission
  - iii) Progress Report No. 1 dated October 24, 1977 on in-stack SO<sub>2</sub> Monitor - INCO.

TABLE VI

## INCO LIMITED

AVERAGE SO<sub>2</sub> EMISSIONS FROM THE  
COPPER CLIFF IRON ORE RECOVERY PLANT (tons per day)

| <u>Date</u> | <u>Emission Level</u> |
|-------------|-----------------------|
| 1960        | 425                   |
| 1970        | 664                   |
| 71          | 874                   |
| 72          | 772                   |
| 73          | 307                   |
| 74          | 225                   |
| 75          | 120                   |
| 76          | 125                   |
| 77          | 158                   |

NOTE:

- (1) Emission levels represent yearly total emissions (based on daily mass balances) divided by 365.
- (2) Emission levels include small contribution emitted from Iron Ore Recovery Plant - pellet plant stacks, estimated to be approximately 5 TPD.
- (3) Reference:
  - i) 1977 Fourth Quarter Report - INCO
  - ii) July 5, 1976 - INCO Program Submission

TABLE VII

## INCO LIMITED

ASSESSMENT OF VARIATIONS IN SO<sub>2</sub> CONTRIBUTIONS (TONS/HR)

TO THE I.O.R.P. - 637' CHIMNEY

| <u>SOURCE</u>                             | <u>MODE OF OPERATION</u>                                                                                                                      | <u>EMISSION LEVEL</u> |      |
|-------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------|-----------------------|------|
| I.O.R.P. Main Flue,<br>including kiln gas | a) steady state, 5<br>roaster/kiln lines operating<br>at 2500 TPD of pyrrhotite<br>concentrate feed at 35.8% S.                               | 0.43                  |      |
|                                           | b) unsteady state-same as (a)<br>above with one roaster damper<br>tripped 100% open for the 1 hr.<br>period (C.I.L. down for 1 roaster)       | 15.27                 |      |
|                                           | c) unsteady state-same as (a)<br>above with one roaster damper<br>tripped 100% open for 1 hr.<br>period (50% of damper trip gas<br>to C.I.L.) | 7.81                  |      |
| C.I.L. - Acid Plant<br>tail gas           | a) steady state 94% (normal)<br>conversion efficiency, combined<br>rated capacity of 3000 TPD<br>assuming steady state conditions<br>above.   | 4.48                  |      |
|                                           | b) same as (a) above but at 92%<br>conversion efficiency                                                                                      | 5.97                  |      |
| Copper Cliff Nickel<br>Refinery flue gas  | emissions from CCNR under various<br>operating modes.                                                                                         |                       |      |
|                                           | <u>A converter</u>                                                                                                                            | <u>B converter</u>    |      |
|                                           | a) charge/melt                                                                                                                                | down                  | 0.57 |
|                                           | b) blow                                                                                                                                       | reduction             | 8.65 |
|                                           | c) average daily (1976 production)                                                                                                            |                       | 1.62 |

TABLE VIII

## INCO LIMITED

ASSESSMENT OF SO<sub>2</sub> EMISSIONS FROM THE IORP

637' CHIMNEY (tons per hour)

| <u>Condition</u>                                                                                                                                                       | <u>Emission Level</u> |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------|
| 1. Normal conditions of IORP, i.e. minimal/no butterfly damper trips, daily average conditions at CCNR, acid plants normal.                                            | 6.58                  |
| 2. Normal operation of IORP, i.e. minimal/no butterfly damper trips, maximum emissions from CCNR, acid plants normal.                                                  | 13.56                 |
| 3. One butterfly damper open 100% during hour at IORP (50% of gas to CIL i.e. CIL fan running) daily average conditions at CCNR and acid plants.                       | 12.98                 |
| 4. One butterfly damper open 100% during hour at IORP (all gas to stack ie CIL down), daily average conditions at CCNR, acid plants normal.                            | 20.44                 |
| 5. One butterfly damper open 100% during hour at IORP (50% of gas to CIL i.e. CIL fan running), average conditions at acid plants, maximum hourly emissions from CCNR. | 20.01                 |
| 6. One butterfly damper open 100% during hour at IORP, maximum hourly emissions at CCNR, acid plants normal.                                                           | 27.47                 |
| 7. Normal operation of IORP (minimal/no butterfly damper trips), daily average condition at CCNR, acid plants operating at 92% conversion efficiency.                  | 8.02                  |
| 8. Same as (7) except maximum hourly emissions from CCNR.                                                                                                              | 15.05                 |

TABLE IX

INCO LIMITED  
CALCULATED GROUND LEVEL CONCENTRATIONS  
OF SO<sub>2</sub> FOR THE COPPER CLIFF SMELTER

1250' Chimney

|                                                                                  | <u>C Stability</u> |
|----------------------------------------------------------------------------------|--------------------|
| Maximum SO <sub>2</sub> half hour average<br>Concentrations (ug/m <sup>3</sup> ) | 594                |
| Critical wind speed (m/sec)                                                      | 9.0                |
| Critical distance (m)                                                            | 11,140             |

NOTE:

1. Q = 37,833 gm/sec.
2. u varies from 2.235 m/sec to 18.235 m/sec.
3. stack temperature = 3000° F.
4. stack gas volume = 6,000,000 ACFM
5. Standard is 830 ug/m<sup>3</sup> half hour average

Low Level Emissions

| <u>C Stability</u>                                                       |                 | <u>D Stability</u>                                                       |                 |
|--------------------------------------------------------------------------|-----------------|--------------------------------------------------------------------------|-----------------|
| SO <sub>2</sub> Half Hour Average<br>Concentrations (ug/m <sup>3</sup> ) | Distance<br>(m) | SO <sub>2</sub> Half Hour Average<br>Concentrations (ug/m <sup>3</sup> ) | Distance<br>(m) |
| 8,203                                                                    | 500             | 15,603                                                                   | 500             |
| 4,237                                                                    | 1000            | 11,135                                                                   | 1000            |
| 417                                                                      | 5000            | 2,242                                                                    | 5000            |
| 132                                                                      | 10000           | 927                                                                      | 10000           |
| 66                                                                       | 15000           | 549                                                                      | 15000           |

NOTE:

1. Q = 1576 gm/sec.  
Wind Oriented Building Width = 1000'  
Building Height = 150'
2. Standard is 830 ug/m<sup>3</sup> half hour average.

TABLE X

INCO LIMITED  
CALCULATED GROUND LEVEL CONCENTRATIONS  
OF SO<sub>2</sub> FOR THE IORP - 637' CHIMNEY

250 TPD

| <u>Wind Speed u</u> | <u>SO<sub>2</sub> Half Hour Average Conc. (ugm/m<sup>3</sup>)</u> |                    |
|---------------------|-------------------------------------------------------------------|--------------------|
| <u>(m/sec)</u>      | <u>C-Stability</u>                                                | <u>D-Stability</u> |
| 2.235               | 554                                                               | .16                |
| 3.0                 | 547                                                               | 1.7                |
| 4.0                 | 492                                                               | 6.9                |
| 5.0                 | 433                                                               | 13.8               |
| 6.0                 | 383                                                               | 40.7               |
| 7.0                 | 342                                                               | 51.2               |
| 7.5                 | 757                                                               | 23.3               |
| 8.0                 | 710                                                               | 21.8               |
| 9.0                 | 631                                                               | 19.4               |
| 10.0                | 568                                                               | 17.4               |

| <u>Emission Level</u> |       | <u>SO<sub>2</sub> Concentrations (3)</u> |                    | <u>SO<sub>2</sub> Concentrations (4)</u> |                    |
|-----------------------|-------|------------------------------------------|--------------------|------------------------------------------|--------------------|
| <u>(ton/hr)</u>       |       | <u>(ugm/m<sup>3</sup>)</u>               |                    | <u>(ugm/m<sup>3</sup>)</u>               |                    |
|                       |       | <u>C-Stability</u>                       | <u>D-Stability</u> | <u>C-Stability</u>                       | <u>D-Stability</u> |
| 1                     | 6.58  | 350                                      | .10                | 478                                      | 14.7               |
| 2                     | 13.56 | 721                                      | .21                | 985                                      | 30.4               |
| 3                     | 12.98 | 690                                      | .20                | 943                                      | 29.1               |
| 4                     | 20.44 | 1087                                     | .31                | 1485                                     | 45.8               |
| 5                     | 20.01 | 1064                                     | .31                | 1454                                     | 44.8               |
| 6                     | 27.47 | 1460                                     | .42                | 1999                                     | 61.5               |
| 7                     | 8.02  | 426                                      | .12                | 584                                      | 18.0               |
| 8                     | 15.05 | 800                                      | .23                | 1095                                     | 33.7               |

NOTE:

- (1) Vs = 5.0 m/sec for U < 1½ Vs, Vs = 0 m/sec for U > 1½ Vs.
- (2) Emission Level noted for conditions outlined in Table V.
- (3) u = 2.235 m/sec Vs = 5.0 m/s, distance = 5300 m
- (4) u = 7.5 m/sec Vs = 0.0 m/s, distance = 2400 m
- (5) SO<sub>2</sub> Concentrations based on 1/2 hour average.
- (6) Standard for SO<sub>2</sub> is 830 ug/m<sup>3</sup> for 1/2 hour average.

TABLE XI

## INCO LIMITED

SUDBURY BASIN SO<sub>2</sub> MONITORING NETWORK DATA 1976-1977

(LEVELS ATTRIBUTED TO SURVEYED INCO SOURCES)

| <u>Station</u> | <u>No. of Hours<br/>&gt;.25 PPM</u> | <u>No. of Hours<br/>&gt;.50 PPM</u> |
|----------------|-------------------------------------|-------------------------------------|
| Lake Penage    | 17                                  | 2                                   |
| Burwash        | 22                                  | 1                                   |
| Callum         | 9                                   | 0                                   |
| Hanmer         | 66                                  | 13                                  |
| Rayside        | 17                                  | 3                                   |
| Garson         | 57                                  | 4                                   |
| Ash            | 69                                  | 2                                   |
| Morgan         | 15                                  | 3                                   |
| St. Charles    | 8                                   | 0                                   |
| Coniston       | 25                                  | 2                                   |
| Lockerby       | 43                                  | 11                                  |
| New Sudbury    | 78                                  | 17                                  |



TABLE XII

## INCO LIMITED

Copper Cliff Smelter 1250' Chimney Particulate/Acid Emissions

Loadings (tons/day)

| <u>Elements</u>                | <u>1973</u> | <u>1974</u> | <u>1975</u> | <u>1976</u> | Ground<br>Level<br>Conc.<br>ug/m <sup>3</sup> | <u>Standard</u><br>ug/m <sup>3</sup> |
|--------------------------------|-------------|-------------|-------------|-------------|-----------------------------------------------|--------------------------------------|
| Cu                             | 1.70        | 1.44        | 0.77        | 0.66        | 0.28                                          | 100                                  |
| Ni                             | 1.21        | 1.63        | 0.39        | 0.58        | 0.27                                          | 5                                    |
| Fe                             | 6.02        | 6.48        | 1.65        | 1.97        | 1.07                                          | 75                                   |
| Pb                             | 0.53        | 0.80        | 0.59        | 0.32        | 0.13                                          | 10                                   |
| As                             | 0.28        | 0.23        | 0.59        | ----        | 0.10                                          | 75                                   |
| H <sub>2</sub> SO <sub>4</sub> | 16.7        | 27.5        | 48.8        | ----        | 8.10                                          | 100                                  |

NOTE:

- (1) Wind speed = 9.05 m/s, distance = 11,140 metres  
Loading = highest # from test results.

|                        |             |                            |
|------------------------|-------------|----------------------------|
| (2) Testing Frequency: | <u>Year</u> | <u># of tests averaged</u> |
|                        | 1973        | 10                         |
|                        | 1974        | 4                          |
|                        | 1975        | 2                          |
|                        | 1976        | 2                          |

- (3) Ground level concentration calculated based on maximum emission number.

TABLE XIII

## INCO LIMITED

## Copper Cliff Smelter Estimated Low Level Emissions

| <u>Element</u> | <u>1974 #4 Nickel Roof Monitor<br/>tons/day</u> | <u>1974 #15 Copper Monitor<br/>tons/day</u> |
|----------------|-------------------------------------------------|---------------------------------------------|
| Cu             | 0.022                                           | 0.150                                       |
| Ni             | 0.017                                           | 0.010                                       |
| Fe             | 0.028                                           | 0.009                                       |
| Pb             | < .001                                          | < .001                                      |
| As             | < .001                                          | < .001                                      |
| Particulate    | 0.191                                           | 0.281                                       |

(1) Average of August 8 and September 4, 1974 testing.

(2) # 15 Copper Monitor - Traversing Probe, July 3, 1974.

Estimated Total Low Level Emission Loading from  
Nickel and Copper Converters

| <u>Element</u> | <u>Loading<br/>(T/D)</u> |
|----------------|--------------------------|
| Cu             | 1.10                     |
| Ni             | 0.21                     |
| Fe             | 0.31                     |
| Pb             | < .015                   |
| As             | < .015                   |
| Particulate    | 3.40                     |

TABLE XIV

## INCO LIMITED

## Iron Ore Recovery Plant (637' Chimney Data)

| <u>COMPONENT</u> | <u>Standard</u><br>(ug/m <sup>3</sup> ) | Condition<br>1   |                             | Condition<br>2   |                             | Condition<br>3   |                             |
|------------------|-----------------------------------------|------------------|-----------------------------|------------------|-----------------------------|------------------|-----------------------------|
|                  |                                         | Loading<br>(T/D) | GLC<br>(ug/m <sup>3</sup> ) | Loading<br>(T/D) | GLC<br>(ug/m <sup>3</sup> ) | Loading<br>(T/D) | GLC<br>(ug/m <sup>3</sup> ) |
| Particulate      | 100                                     | 8.78             | 19.5                        | 9.14             | 20.2                        | 4.4              | 9.7                         |
| Cu               | 100                                     | 0.87             | 1.9                         | 1.57             | 3.5                         | 0.16             | 0.4                         |
| Ni               | 5                                       | 2.35             | 5.2                         | 0.73             | 1.6                         | 0.16             | 0.4                         |
| Fe               | 75                                      | 2.22             | 4.9                         | 2.03             | 4.5                         | 2.02             | 4.5                         |
| Pb               | 10                                      | < .01            | < .05                       | 0.04             | 0.1                         | 0.03             | 0.07                        |

NOTE:

- (1) Nickel Refinery TBRC charging plus average loadings from the Iron Ore Recovery Plant.
- (2) Nickel Refinery TBRC blowing plus average loadings from the Iron Ore Recovery Plant.
- (3) Nickel Refinery TBRC in reduction phase plus average loadings from the Iron Ore Recovery Plant.
- (4) 1976 test data used (one converter operation at nickel refinery, no contributions from acid plants).
- (5) GLC = ground level concentration  
GLC's based on half hour average loading.

TABLE XV

## INCO LIMITED

DUST EMISSION (tons per day) FROM ROUTINE TESTING (103)

AT THE COPPER CLIFF NICKEL REFINERY FOR A ONE CONVERTER OPERATION

| <u>Phase</u>                                                            | <u>Charge</u> | <u>Blow</u> | <u>Reduction</u> |
|-------------------------------------------------------------------------|---------------|-------------|------------------|
| Average loading                                                         | 2.25          | 2.84        | 0.80             |
| Range      High                                                         | 9.27          | 6.85        | 1.94             |
| Low                                                                     | 0.60          | 0.81        | 0.05             |
| 95% Confidence loadings                                                 | 5.15          | 5.38        | 1.69             |
| Standard Deviation                                                      | 1.76          | 1.54        | 0.54             |
| Nickel (ug/m <sup>3</sup> ) half<br>hour ground level<br>concentrations | 4.7           | 1.4         | 0.5              |

NOTE:

Following criteria was used to calculate glc's

- 1976 testing, charge 42% nickel  
                    blow 11.8% nickel  
                    reduction 13.1% nickel
- stack exit velocity 5 m/s
- wind velocity 2.5 m/s
- C-Stability
- Loadings from 95% confidence column, assuming no contribution from Iron Ore Recovery Plant and CIL acid plants.

TABLE XVI

## INCO LIMITED

## ANALYSIS OF HIGH VOLUME AIR FILTERS

EXPOSED IN THE SUDBURY AREA IN 1976 AND 1977

| <u>Element</u> | <u>Station</u> | <u>No. of Samples Analyzed</u> |             | <u>Max. 24-Hr. Value (ug/m<sup>3</sup>)</u> |             | <u>Geometric Mean (ug/m<sup>3</sup>)</u> |             |
|----------------|----------------|--------------------------------|-------------|---------------------------------------------|-------------|------------------------------------------|-------------|
|                |                | <u>1976</u>                    | <u>1977</u> | <u>1976</u>                                 | <u>1977</u> | <u>1976</u>                              | <u>1977</u> |
| Cu             | Ash St         | 49                             | 40          | 4.4                                         | 2.9         | 0.5                                      | 0.5         |
|                | Lisgar St      | 47                             | 55          | 1.3                                         | 1.4         | 0.4                                      | 0.5         |
|                | Copper Cliff   | 15                             | 43          | 3.7                                         | 2.2         | 1.4                                      | 0.8         |
| Ni             | Ash St         | 49                             | 40          | 1.4                                         | 1.2         | 0.14                                     | 0.15        |
|                | Lisgar St      | 47                             | 55          | 0.9                                         | 0.5         | 0.13                                     | 0.08        |
|                | Copper Cliff   | 15                             | 43          | 2.2                                         | 1.1         | 0.23                                     | 0.17        |
| Fe             | Ash St         | 49                             | 40          | 8.1                                         | 7.4         | 1.3                                      | 1.0         |
|                | Lisgar St      | 47                             | 55          | 9.6                                         | 1.1         | 1.9                                      | 1.2         |
| T.S.P.         | Ash St         | 57                             | 52          | 91                                          | 109         | 33                                       | 35          |
|                | Lisgar St      | 51                             | 55          | 107                                         | 114         | 47                                       | 43          |
|                | Copper Cliff   | 16                             | 48          | 90                                          | 306         | 56                                       | 44          |

NOTE:

| <u>Element</u> | <u>Air Quality Criteria (ug/m<sup>3</sup>)</u><br><u>(24 hour average)</u> |
|----------------|----------------------------------------------------------------------------|
| Cu             | 50                                                                         |
| Ni             | 2.0                                                                        |
| Fe             | -                                                                          |
| TSP            | 120 (60 - geometric mean)                                                  |

TABLE XVII

## INCO LIMITED

## IRON ORE RECOVERY PLANT - AMMONIA BALANCES - 1977

| <u>Month</u> | <u>Process Ammonia<br/>Consumption (T/D)</u> | <u>Liquid Effluent<br/>Ammonia Loss (T/D)</u> | <u>Atmospheric Ammonia<br/>Loss (T/D)</u> |
|--------------|----------------------------------------------|-----------------------------------------------|-------------------------------------------|
| January      | 14.4                                         | 4.6                                           | 9.8                                       |
| February     | 14.9                                         | 5.7                                           | 9.2                                       |
| March        | 17.2                                         | 5.7                                           | 11.5                                      |
| April        | 17.7                                         | 5.6                                           | 12.1                                      |
| May          | 16.9                                         | 4.0                                           | 12.9                                      |
| June         | 25.7                                         | 5.7                                           | 20.0                                      |
| July         | 33.4                                         | 7.3                                           | 26.1                                      |
| August       | 17.2                                         | 6.1                                           | 11.1                                      |
| September    | 18.1                                         | 6.1                                           | 12.0                                      |
| October      | 18.2                                         | 7.1                                           | 11.0                                      |
| November     | 17.6                                         | 6.2                                           | 11.4                                      |
| December     | 10.4                                         | 4.6                                           | 5.8                                       |
| AVERAGE      | 15.7                                         | 5.9                                           | 10.8                                      |

TABLE XVIII

## INCO LIMITED

## COPPER CLIFF CREEK - IRON ORE RECOVERY PLANT - DATA

| <u>Month</u><br><u>1977</u> | <u>Copper Cliff Creek</u> |                       |              | <u>Iron Ore Recovery Plant</u> |                            |
|-----------------------------|---------------------------|-----------------------|--------------|--------------------------------|----------------------------|
|                             | Flow<br>(cfs)             | TKN<br>Conc.<br>(ppm) | TKN<br>(T/D) | Effluent<br>Load               | AMMONIA LOSS as N<br>(T/D) |
| January                     | 20.4                      | 86                    | 5.7          |                                | 3.8                        |
| February                    | 26.2                      | 78                    | 6.6          |                                | 4.7                        |
| March                       | 83.4                      | 42                    | 11.3         |                                | 4.7                        |
| April                       | 56.2                      | 48                    | 8.7          |                                | 4.6                        |
| May                         | 30.1                      | 72                    | 7.0          |                                | 3.3                        |
| June                        | 39.6                      | 52                    | 6.6          |                                | 4.7                        |
| July                        | 13.8                      | 53                    | 2.4          |                                | 6.0                        |
| August                      | 15.5                      | 54                    | 2.7          |                                | 5.0                        |
| September                   | 16.7                      | 58                    | 3.1          |                                | 5.0                        |
|                             |                           | Average               | 6.0          |                                | 4.6                        |

NOTE:

- (1) TKN = total kjeldahl nitrogen as N - includes all forms of organic nitrogen, including ammonia.

TABLE XIX

## INCO LIMITED

SUMMARY OF VERP SYSTEM PERFORMANCE DURING 1976-1977 BASED  
ON HOURLY AVERAGE CONCENTRATIONS OF SO<sub>2</sub> (>.50 ppm) MEASURED  
BY M.O.E. MONITORS

| <u>Year</u> | <u>Quarter</u> | <u>Equiv. Hrs.<br/>at 100%<br/>Reduction</u> | <u>Days &gt;.5 ppm<br/>Anticipated</u> | <u>Days &gt;.5 ppm<br/>Not Antici-<br/>pated</u> | <u>Days &gt;.5 ppm<br/>With<br/>Controls</u> | <u>Hrs. &gt;.5 ppm<br/>With<br/>Controls</u> |
|-------------|----------------|----------------------------------------------|----------------------------------------|--------------------------------------------------|----------------------------------------------|----------------------------------------------|
| 1976        | First          | 0                                            | 0                                      | 0                                                | 0                                            | 0                                            |
| 1977        |                | 0                                            | 0                                      | 1                                                | 0                                            | 0                                            |
| 1976        | Second         | 49.0                                         | 26                                     | 4                                                | 6                                            | 13                                           |
| 1977        |                | 59.6                                         | 25                                     | 5                                                | 4                                            | 10                                           |
| 1976        | Third          | 38.0                                         | 21                                     | 3                                                | 5                                            | 6                                            |
| 1977        |                | 33.1                                         | 20                                     | 2                                                | 3                                            | 3                                            |
| 1976        | Fourth         | 0                                            | 0                                      | 0                                                | 0                                            | 0                                            |
| 1977        |                | 10.1                                         | 8                                      | 1                                                | 2                                            | 2                                            |
| TOTALS      |                | 189.8                                        | 100                                    | 16                                               | 20                                           | 34                                           |

NOTE:

1. 830 ug/m<sup>3</sup> SO<sub>2</sub> is equivalent to 0.30 ppm SO<sub>2</sub>.
2. 0.25 ppm is the Ontario Ambient Air Quality Criterion.





(8130)

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MOE/SUD/REP/ALSS 1978  
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